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Sea Ice Fluctuations in the Western Labrador Sea (1963-1988)

I.K. Peterson and S.J. Prinsenberg

Physical and Chemical Sciences Branch
Scotia-Fundy Region
Department of Fisheries and Oceans

Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, Nova Scotia
Canada B2Y 4A2

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ABSTRACT

Peterson, I.K. and S. J. Prinsenberg. 1990. Sea ice fluctuations in the western Labrador Sea (1963-1988). Can. Tech. Rep. Hydrogr. Ocean Sci. No. 123:iv + 130 pp.

This atlas describes sea ice fluctuations in the western Labrador Sea for the years 1963 to 1988 inclusive. The data set consists of ice concentration data on a 0.5° latitude by 1.0° longitude grid, derived from weekly ice charts published by the Atmospheric Environment Service. The data set was compiled from several sources, each covering different periods. The ice charts were digitized between 45 and 65°N with respect to total ice concentration, and the concentration of individual ice types (new, grey, grey-white, first-year and old). Monthly maps showing total ice concentration and the relative concentrations of the various ice types are presented. Time series of sea ice extent, ice extent anomalies, air temperature and geostrophic wind are also included.

RÉSUMÉ

Peterson, I.K. and S. J. Prinsenberg. 1990. Sea ice fluctuations in the western Labrador Sea (1963-1988). Can. Tech. Rep. Hydrogr. Ocean Sci. No. 123:iv + 130 pp.

Cet atlas décrit les fluctuations de la glace de mer dans la mer du Labrador occidentale de 1963 à 1988 inclusivement. L'ensemble de données consiste en concentrations de glace suivant un quadrillage de 0,5° en latitude et 1,0° en longitude dérivées des cartes hebdomadaires des glaces publiées par le Service de l'environnement atmosphérique. L'ensemble de données a été compilé d'après plusieurs sources, chacune couvrant des périodes différentes. Les cartes des glaces ont été numérisées entre 45 et 65°N et on y a relevé la concentration totale de glace ainsi que les concentrations de différents types de glace (nouvelle, grise, blanchâtre, de première années et vieille). Des cartes mensuelles montrant la concentration totale de glace et les concentrations des divers types de glace sont présentées. Des successions chronologiques des étendues recouvertes par la glace de mer, des anomalies de l'étendue recouverte de glace, de la température de l'air et du vent géostrophique sont également présentées.

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1. INTRODUCTION

Sea ice off Labrador and Newfoundland poses a major hazard for shipping and for offshore hydrocarbon exploration and development. Because of the lack of land masses that would block the southward extent of sea ice, the Baffin Bay-Labrador region is one of the most variable in the northern hemisphere in terms of interannual sea ice extent (Walsh and Johnson, 1979). Global ice extent is important in controlling the earth's climate, since sea ice reduces the flux of solar radiation into the ocean, as well as the amount of heat transferred from the ocean to the atmosphere.

Several atlases describing ice conditions in the Labrador Sea region have been published in recent years. Some of them concentrate on describing mean ice conditions for each week of the year, while others describe the interannual variability of ice concentration or extent in the form of time series. For example, charts showing the probability of ice within 0.5° latitude by 1.0° longitude squares for each week of the year are presented for the Southern Labrador/Newfoundland region in Markham (1980), and for the Davis Strait/Labrador region in Markham (1988). In addition, Markham (1980) describes seasonal changes of ice type, i.e. the stages of development of ice. Sowden and Geddes (1980) present charts of the median, minimum and maximum position of the ice edge for each week of the year. These three atlases show the climatological mean ice conditions, as well as a general measure of the interannual variability. On the other hand, Manak and Mysak (1987) have described the interannual variability from 1953 to 1984 for the entire Arctic region by presenting seasonal maps of ice concentration, and time series of ice extext anomalies. This work was based on monthly ice concentration data on a 1° latitude by 1° longitude grid. In these time series, there appear to be cycles of 4-10 years for the various sub-areas.

This atlas describes the interannual variability of sea ice conditions for the western Labrador Sea from 1963 to 1988 on a finer spatial and temporal scale than that used in the atlas of Manak and Mysak (1987). Monthly maps showing total ice concentration and the concentration of individual ice types are based on a data set obtained by digitizing weekly ice charts from the Atmospheric Environment Service, on a 0.5° latitude by 1.0° longitude grid. Time series of sea ice extent, air temperature and geostrophic wind at several locations are also included for reference.

2. DESCRIPTION OF DATA SET

Digitized ice chart data for the early years were compiled from the following sources:

1) 1963-1972 W. E. Markham (Ice Centre, AES)

2) 1973-1978 Esso Resources

For subsequent years, weekly ice charts were obtained from the Ice Centre (AES), and were then digitized by:

1) 1978-1985 Martec Ltd.

2) 1986-1988 45-56°N: Martec Ltd.

3) 1986-1988 56-65°N: M. Murphy, Canadian Seabed Research

The area described in this atlas is enclosed by the heavy line in Figure 1. For the years 1979-1988, the charts that were digitized did not include the area east of the dashed line (at 54°W); thus there are not any data from this region.

The data set consists of the total concentration of ice in each grid square, as well as the concentration of each of the following constituents:

1) New Ice (0-10 cm)

2) Grey Ice (10-15 cm)

3) Grey-White Ice (15-30 cm)

4) First-Year Ice (>30 cm)

5) Old Ice (ice which has survived at least one melt season)

Since 1982, the ice charts have shown more thickness categories, but are not included in the digitized data set.

Some data are missing for the following reasons:

1) There is a lack of satellite observations for the early years, so that total coverage is reduced.

2) Sometimes, the presence of ice is known, but not the concentration.

3) Sometimes, the total concentration is known, but not the concentration of individual ice types.

4) The northern charts digitized since 1979, are only monthly or bi-weekly between January and May. For this reason, and because of limited text space, this atlas displays monthly mean maps, even though the data set consists of weekly digitized data for most areas and times.

The data set obtained for 1963-1972 (see above) was effectively of a higher spatial resolution than later records, since it contained data concerning the position of the ice edge within individual grid squares. However, for consistency with the other data sets, the grid square was assumed to contain ice only if at least 50% of the square was inside the ice edge.

Obvious errors in the data set (1963-1988) were removed after visually inspecting weekly spatial plots of the digitized data. Errors in the concentrations of individual ice types were also detected by comparing the sum of the ice types with the total concentration. These errors were then corrected using surrounding grid squares.

3. PRESENTATION OF DATA SET

The data set is displayed in two ways in Appendices A and B. In Appendix A, charts of the climatological probability of ice occurrence for each month of the year are shown, while Appendix B presents the complete time series of digitized ice charts for the period of 1963 to 1988.

3.1 PROBABILITY OF ICE OCCURRENCE BY MONTH AND GRID SQUARE (APPENDIX A)

The climatological mean probability of ice occurrence within each grid cell was computed for each month for the period, 1963-1987, since only the first 9 months of data for 1988 were available (Appendix A). For each grid cell, the probability was calculated as the number of years when ice was observed in at least one week of the given month, divided by the total number of years with data, and is shown in the plots multiplied by 10, i.e. a probability of 0.9 is shown as 9. The 1000 m isobath is also plotted for reference, and shows a close association between the ice edge and shelf break.

3.2 MONTHLY ICE CHARTS (APPENDIX B)

Monthly mean ice concentrations in each year were computed using all weeks for which there were data, for each 0.5° latitude by 1.0° longitude grid square. The mean total ice concentration is plotted as a circle, its diameter being proportional to the concentration. No symbol is plotted if the mean concentration is less than 0.05. The concentration of each individual ice type is indicated by the length of the corresponding radiating vector, scaled by the concentration of the most common ice type. A question mark indicates that no concentration data were available. A blank grid cell denotes open water. As a means of comparison, the median ice edge position for the month is plotted as a dotted line and represents the limit of grid cells in 1963-87

with an ice probability of at least 0.5 (Appendix B).

4. PRELIMINARY ANALYSIS

The data set used in this atlas was compiled in order to obtain time series of sea ice extent with which to perform regression analyses with atmospheric and oceanographic parameters. Some of the preliminary plots and results will be shown below, with a more rigorous analysis to follow in a later publication.

4.1 SEASONAL AND INTERANNUAL VARIABILITY (1963-1988)

The weekly sea ice extent (total area within the ice edge) is plotted for four latitude bands in Figure 2, with the northernmost band (southern tip of Baffin Island) at the top of the page, and the southernmost band (south of St. John's) at the bottom of the page. Dashed lines indicate where data are missing. For each of these bands, the mean ice extent for each week of the year, was computed from the 26 years of data (Figure 3), along with the weekly minimum and maximum ice extent. The interannual variability in sea ice coverage for the same four bands is shown by the plots of weekly ice extent anomalies (Figure 4). For consistency with the data coverage after 1979, all data east of 54°W before 1979 were excluded for the 61-63°N band in Figures 2, 3 and 4. For this band (61-63°N), the ice extent was high during the 1972-73 and 1983-84 periods, while in the south (45-47°N), there was a significant amount of ice in 1964, 1972-1975 and 1985-1987. At 49-51°N, across the Northeast Newfoundland Shelf, the time series shows a smooth decadal cycle, with peaks in 1972-73 and 1984-85. This cycle is less evident in the 53-55°N band, across the middle of the Labrador shelf (Figure 4). Here, the maximum ice extent is low and relatively constant from January to May (Figure 3),

presumably because the shelf is narrow, with a very sharp shelf break, so that the warm Labrador Sea would tend to stabilize the offshore sea ice extent.

The mean negative air temperatures for the months December-February (Figure 5), show many similarities to the ice time series in Figures 2 and 4. Again, the time series for the northernmost station (Iqaluit), is at the top of the page. At Iqaluit, winter air temperatures were coldest in 1972-73, and 1983-84, while in the south at St. John's, they were cold in 1972-75, and 1985-87. At Cartwright and St. Anthony there were peaks in the negative air temperature time series in 1972-73 and 1983-85.

Geostrophic wind data were computed by AES from gridded pressure data from the Fleet Numerical Oceanographic Center (FNOC) (Swail, 1985). The mean northwesterly and southwesterly components for December-February show high spatial coherence (Figure 6). In general, it can be seen from Figures 5 and 6 that cold temperatures correspond to winters with strong northwesterly winds.

4.2 LONG TIME SERIES PLOTS

For comparison, climatological data over a longer time period are also presented. Miles (1974) defined a sea ice index as the sum of the latitude and longitude corresponding to the maximum southward and eastward extent of sea ice in April, and tabulated values for 1920-1973. Low sea ice values correspond to years with large sea ice coverage. This time series has been extended to 1986, based on International Ice Patrol charts, as used by Miles (Figure 7). The sea ice index was also estimated for the month of March, since this is generally the month of maximum ice extent. As found for ice extent, the sea ice index correlates well with air temperature, ie. colder years correspond to years with a low sea ice index. Also plotted in Figure 7, are the numbers of icebergs south of 48°N (U.S. Coast Guard, 1938-1987), for

each year since 1900. Again, colder years correspond to years when large numbers of icebergs were encountered. Marko et al. (1986) also noted a high correlation between iceberg numbers and ice extent in the Davis Strait area. The decadal period seen in the shorter sea ice data appears to be present for several cycles in the iceberg data, with shorter periods appearing as well. However, the decadal period is not as clearly visible in the ice index data prior to 1970.

Long time series for negative air temperature and geostrophic wind (December-February) are shown in Figures 8 and 9. For St. John's, the circles represent data from a former station location. However, the overlap indicates there is good agreement with the new station, with an offset of about 0.7°C. The high spatial coherence of winter temperatures (Figure 8), can be attributed to large-scale wind patterns (Figure 9). Stronger and more frequent northwesterly winds such as seen in the early to mid-1970's are associated with lower temperatures, presumably because they bring cold Arctic air into the area.

5. CONCLUSIONS

The weekly digitized ice maps will provide an excellent time series with which to perform statistical analyses with atmospheric parameters, in order to study the coupling between ice extent and the atmosphere. Preliminary results indicate a strong ice-atmosphere coupling, with high sea ice extent and iceberg count associated with a high northwesterly wind component and colder air temperatures. The ice extent anomalies show the decadal cycle seen by Mysak and Manak (1989). A significant 11-year cycle was also evident in a principal component analysis of 101 years of winter North Atlantic mean sea level pressure data (Kelly, 1977). The decadal cycle in ice extent has

recently been discussed in terms of ocean-atmosphere feedback loops by Ikeda (1989). Although the spatial coherence of ice extent is high over the entire study area, the north-south differences which do exist appear to be strongly related to north-south differences in atmospheric parameters. These north-south relationships between sea ice and the ocean and atmosphere are being quantified in present research.

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FIGURES

Figure 1. The western Labrador Sea region, showing the area described in this atlas (heavy line). The data set used contains no ice concentration data east of the dashed line for 1979-1988.

Figure 2. Weekly sea ice extent (total area within the ice edge), 1963-1988, for four latitude bands (61-63°N, 53-55°N, 49-51°N, and 45-47°N). Dashed lines indicate missing data. The 1-year running mean is also shown.

Figure 3. Mean ice extent (solid line) and minimum and maximum ice extent (dashed lines) for each week of the year, for the four latitude bands.

Figure 4. Weekly ice extent anomalies, 1963-1988, for the four latitude bands. Dashed lines indicate missing data. The 1-year running mean is also shown.

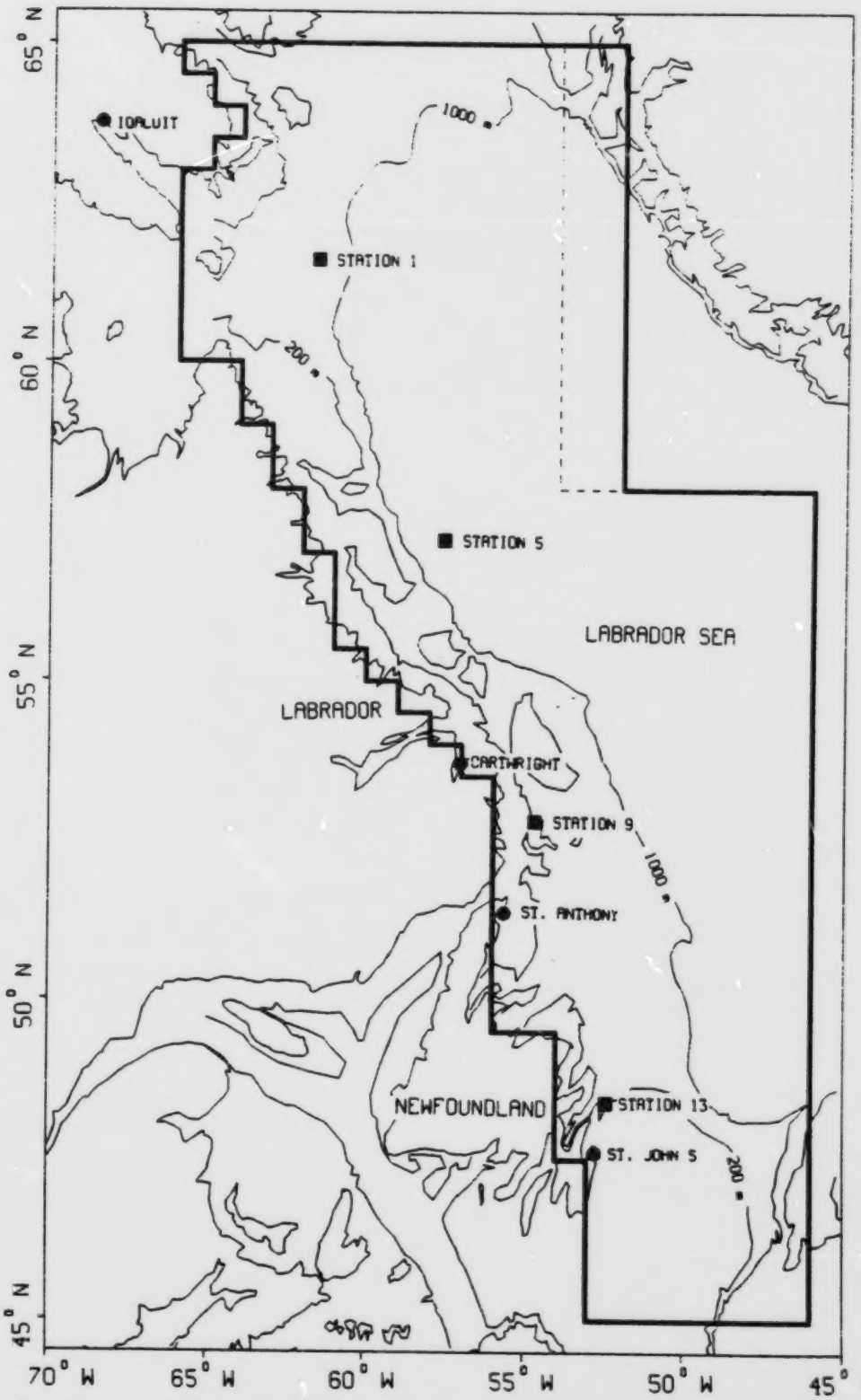
Figure 5. Mean negative air temperature (December - February), 1963-1988, at Iqaluit, Cartwright, St. Anthony, and St. John's. The year refers to February.

Figure 6. Mean geostrophic wind components (December - February), 1963-1988. The year refers to February. The crosses refer to the northwest component (positive from the northwest), while the circles refer to the southwest component (positive from the southwest).

Figure 7. March sea ice index (1938-1986), April sea ice index (1920-1986), and iceberg numbers (1900-1988).

Figure 8. Long time series of mean negative air temperature (December - February), at Iqualuit, Cartwright, St. Anthony and St. John's.

Figure 9. Mean geostrophic wind components (December - February), 1946-1988. The year refers to February. The crosses refer to the northwest component (positive from the northwest), while the circles refer to the southwest component (positive from the southwest).



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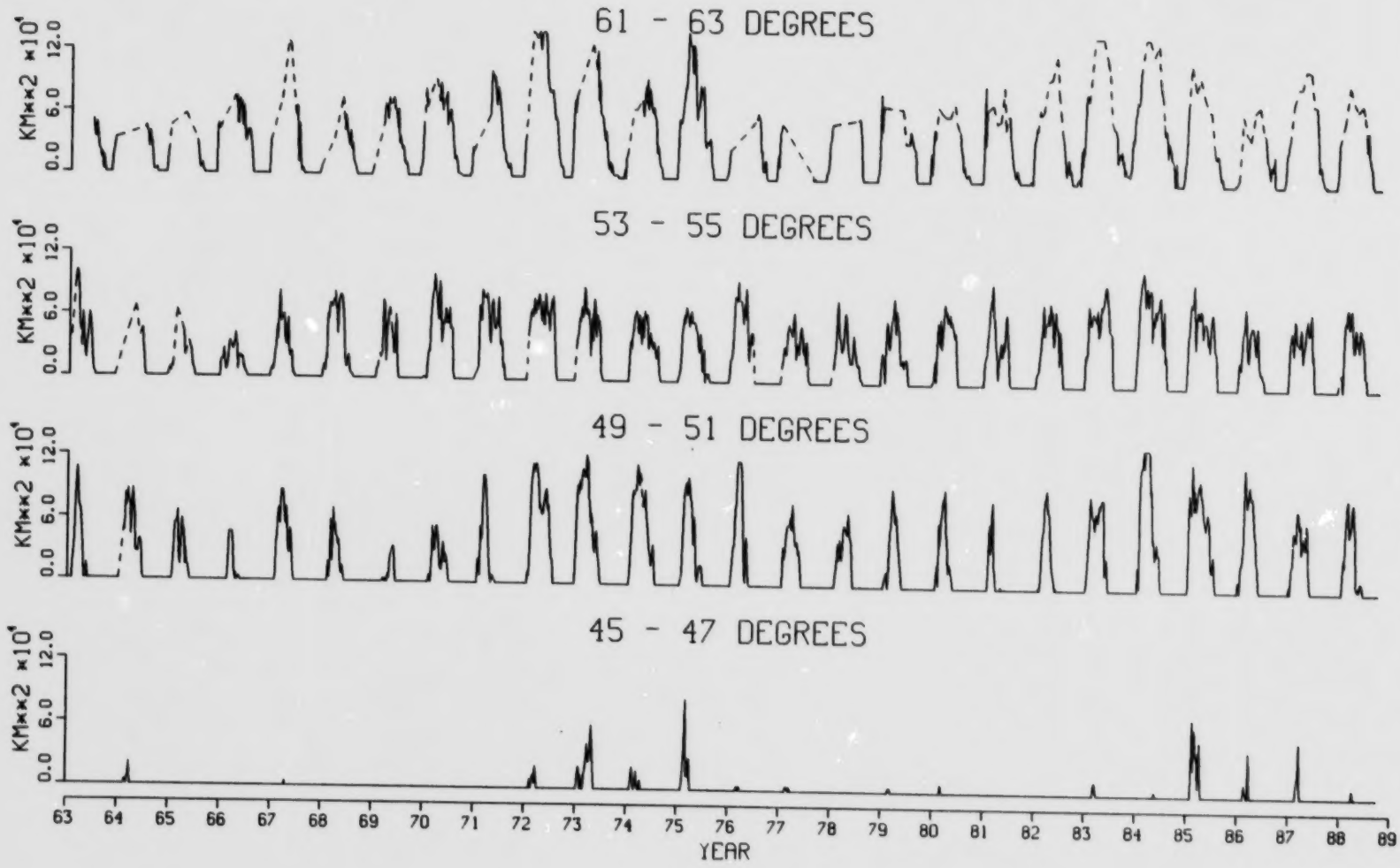

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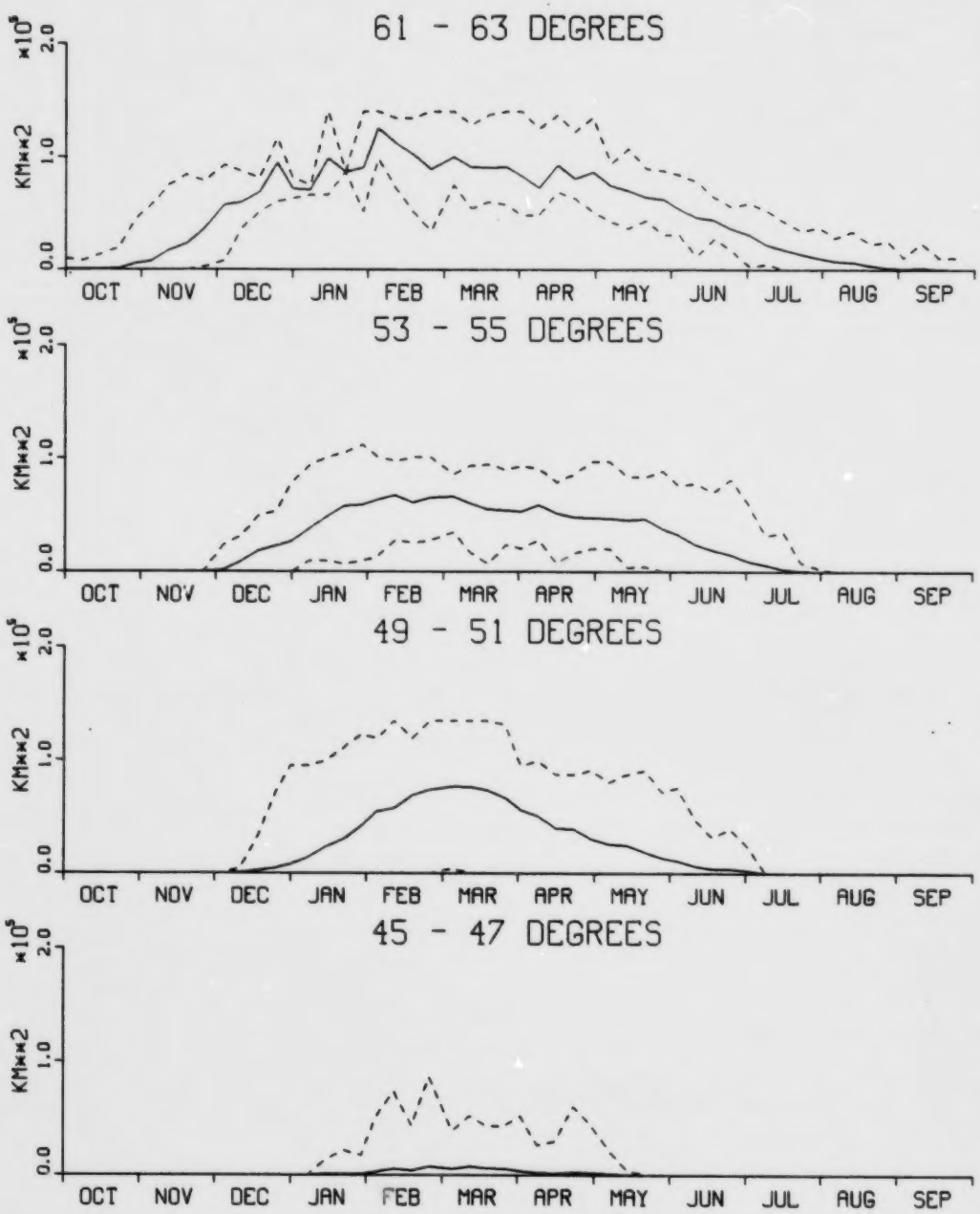


Figure 3. Mean ice extent (solid line) and minimum and maximum ice extent (dashed lines) for each week of the year, for the four latitude bands.

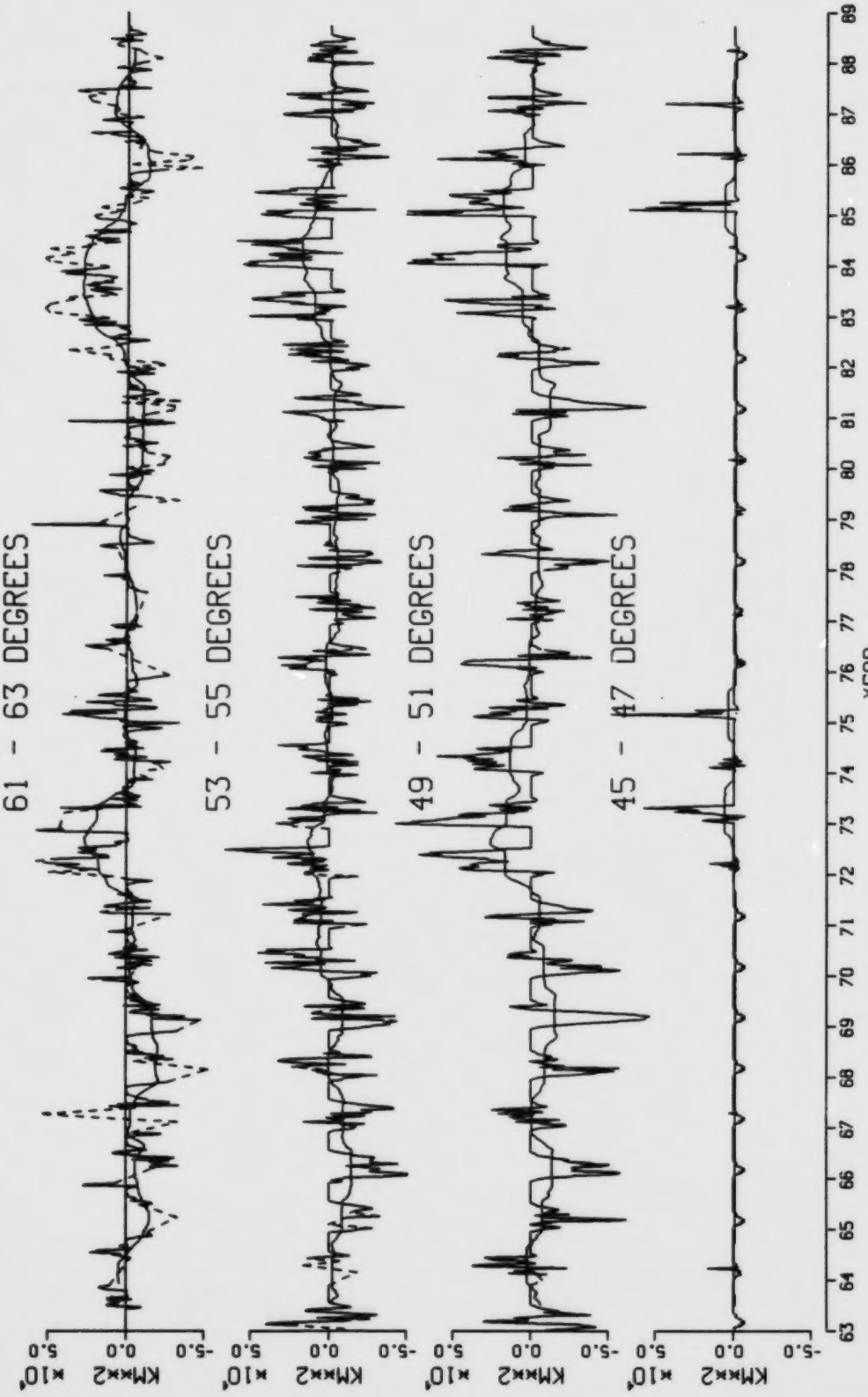


Figure 4. Weekly ice extent anomalies, 1963-1988, for the four latitude bands. Dashed lines indicate missing data. The 1-year running mean is also shown.

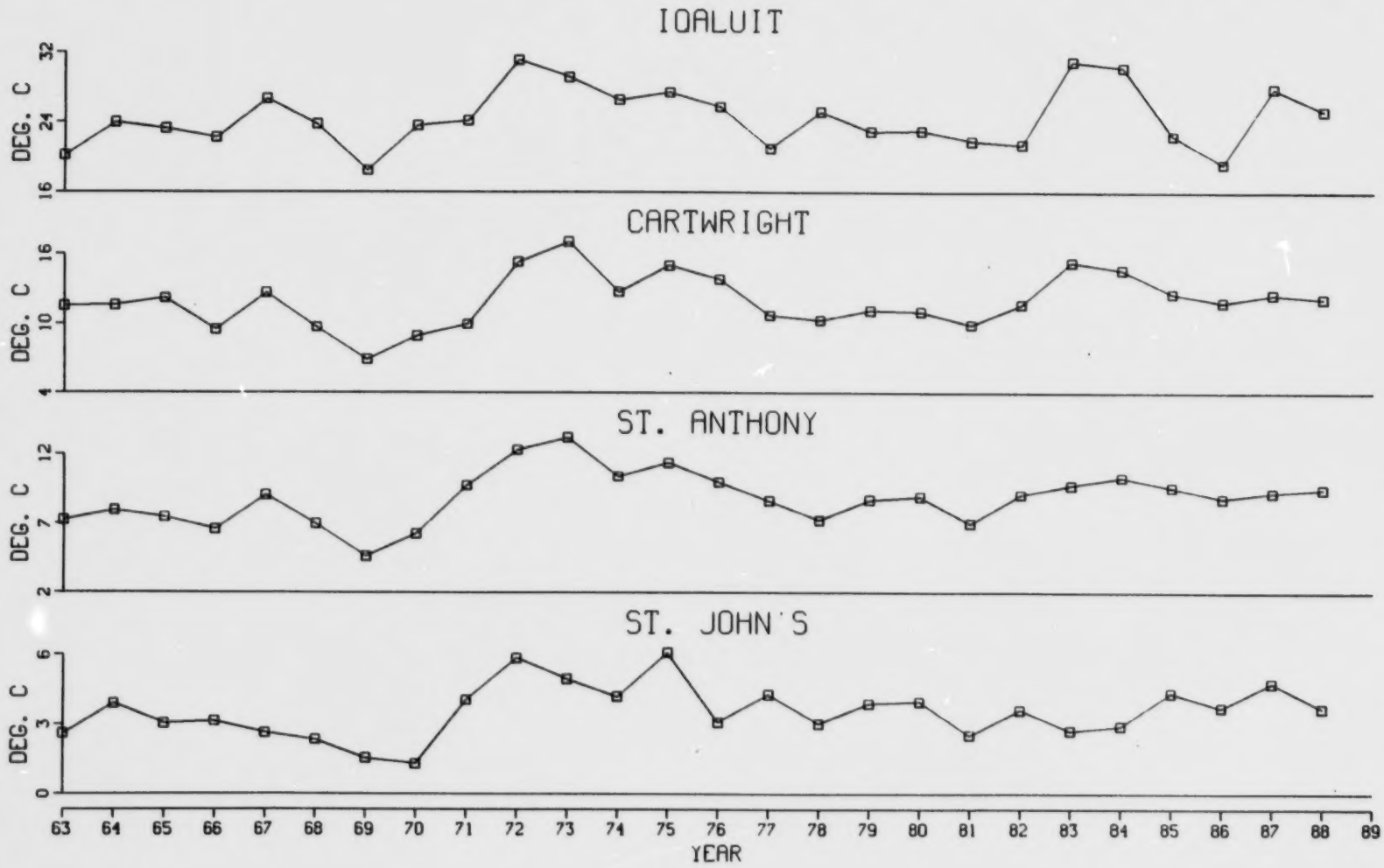


Figure 5. Mean negative air temperature (December - February), 1963-1988, at Iqaluit, Cartwright, St. Anthony, and St. John's. The year refers to February.

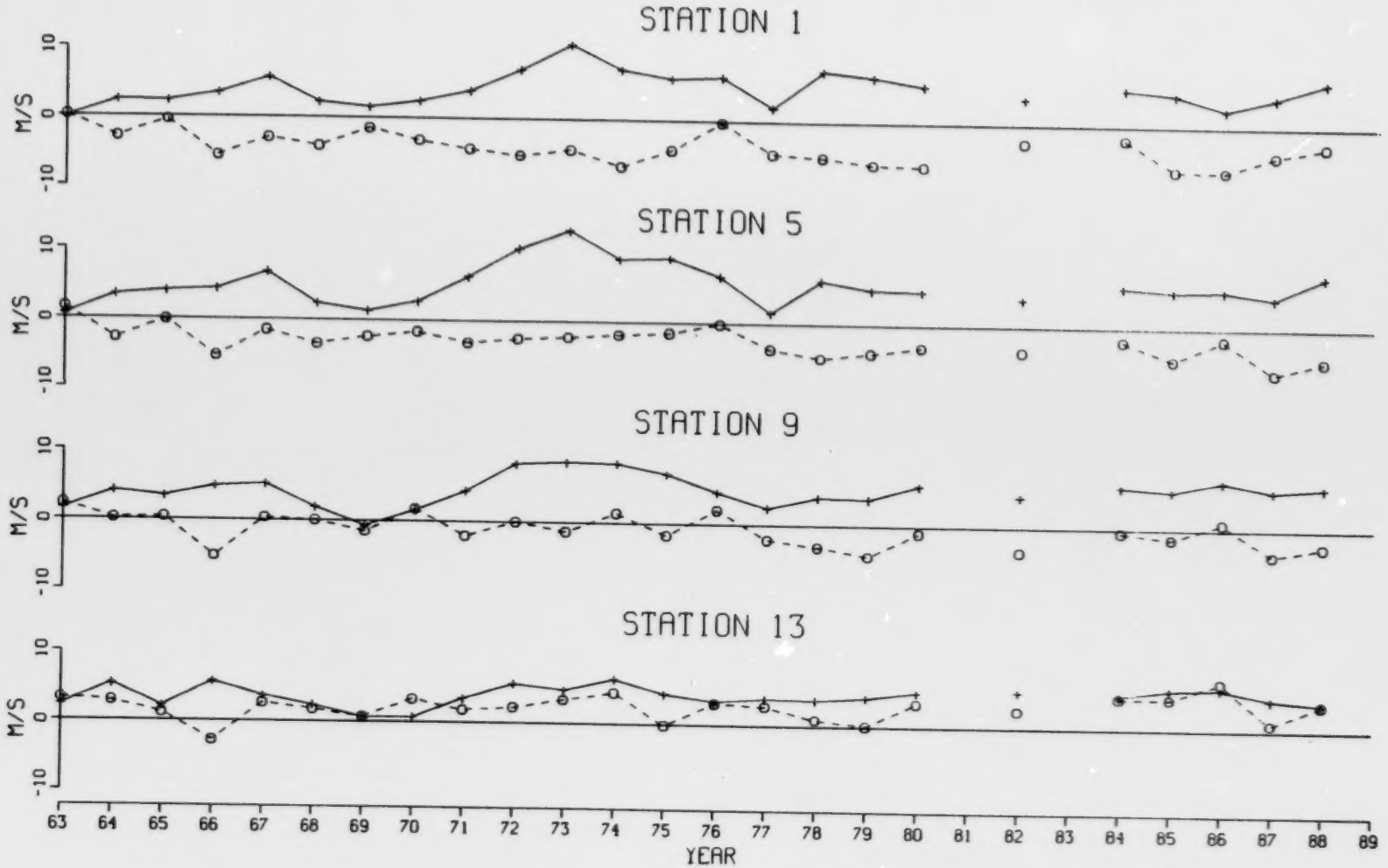
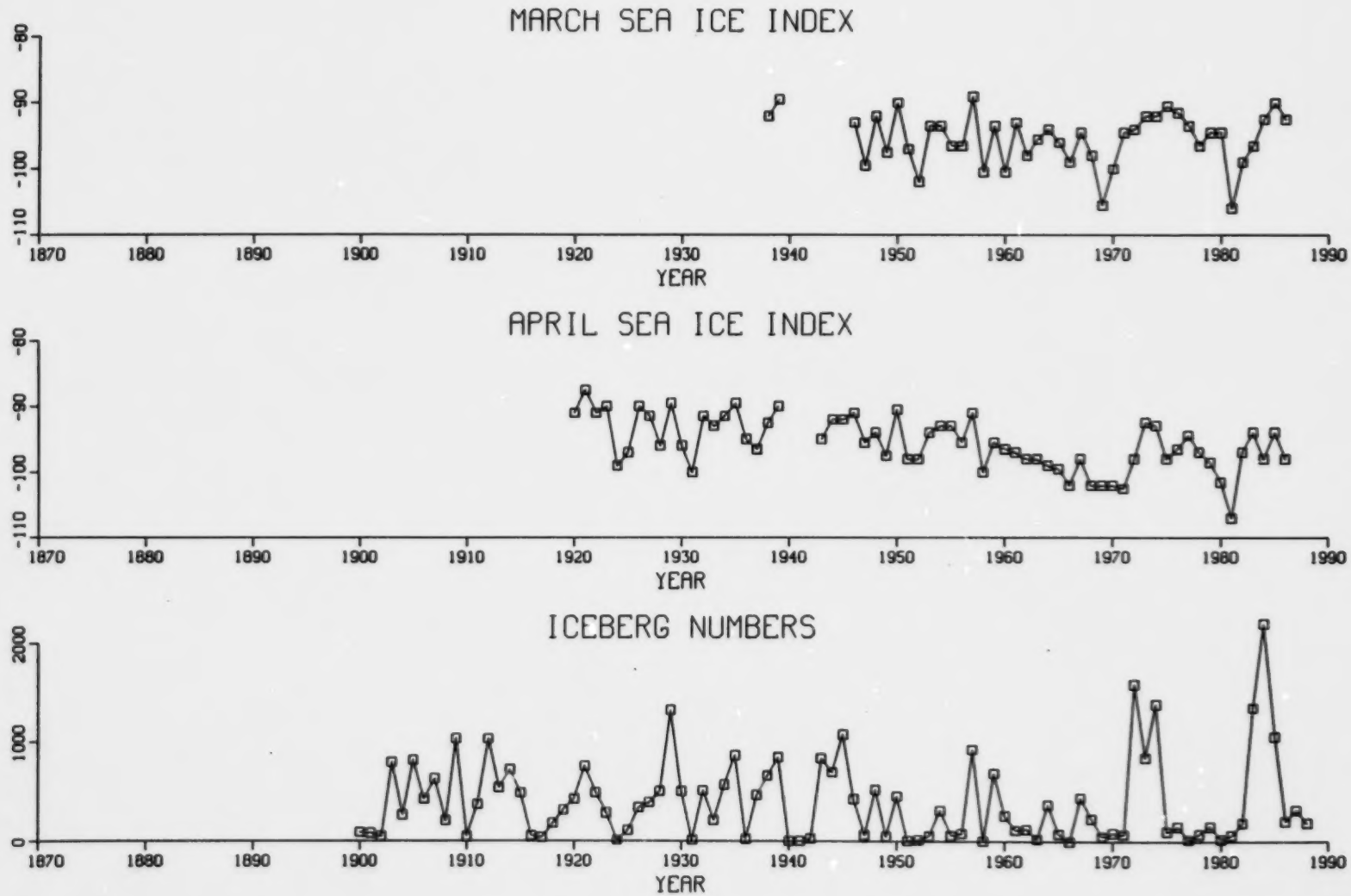


Figure 6. Mean geostrophic wind components (December - February), 1963-1988. The year refers to February. The crosses refer to the northwest component (positive from the northwest), while the circles refer to the southwest component (positive from the southwest).



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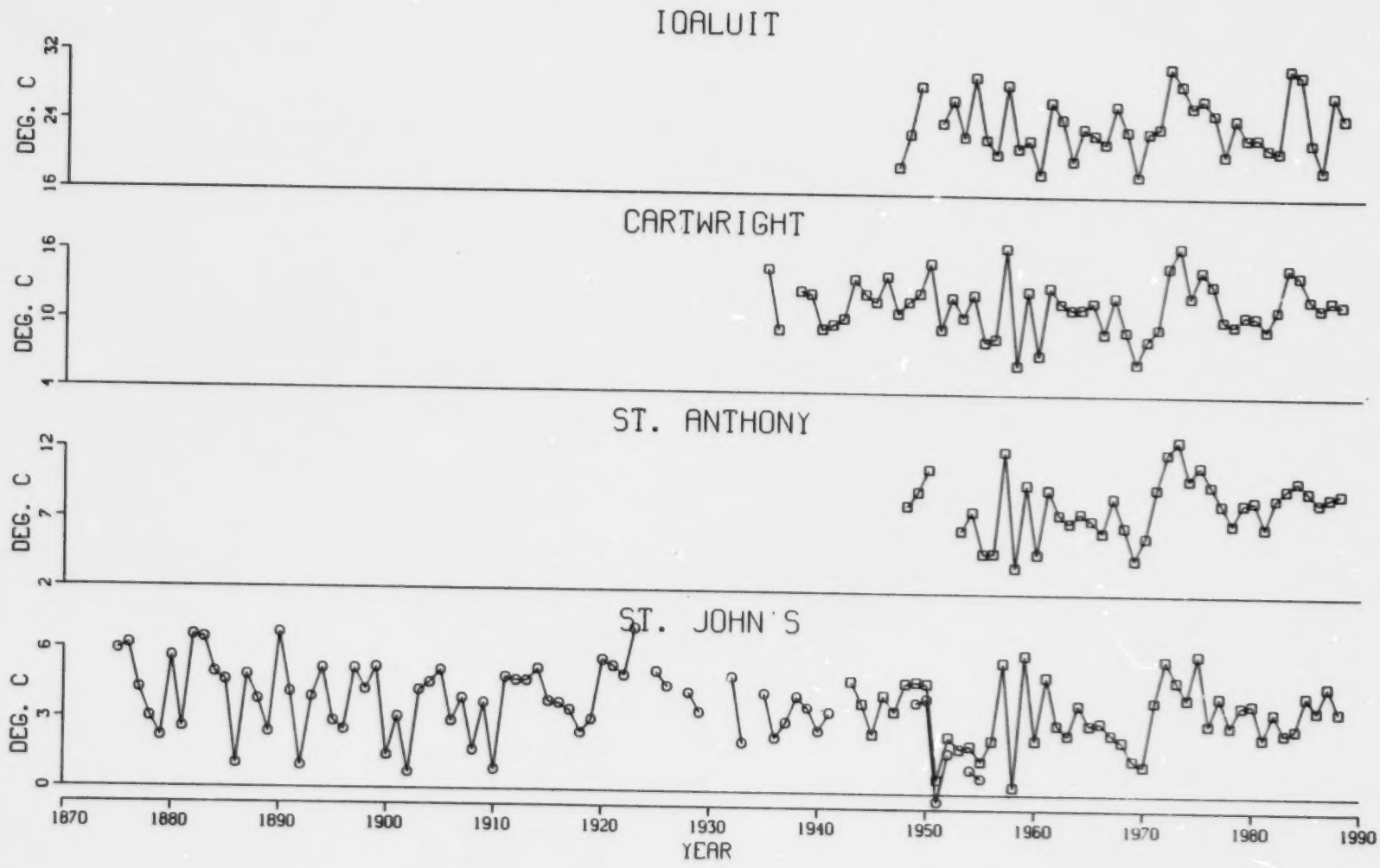


Figure 8. Long time series of mean negative air temperature (December - February), at Iqualuit, Cartwright, St. Anthony and St. John's.

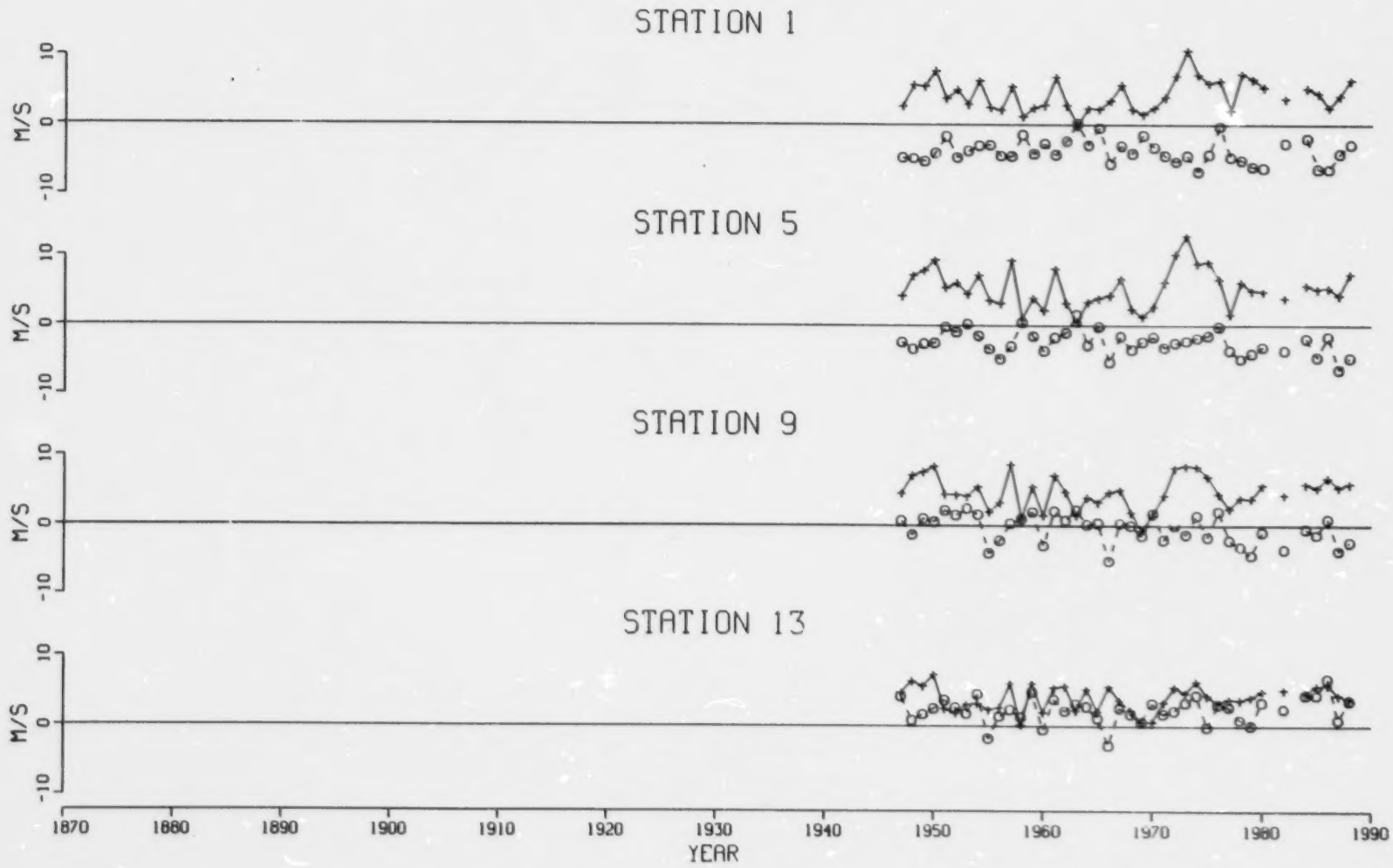
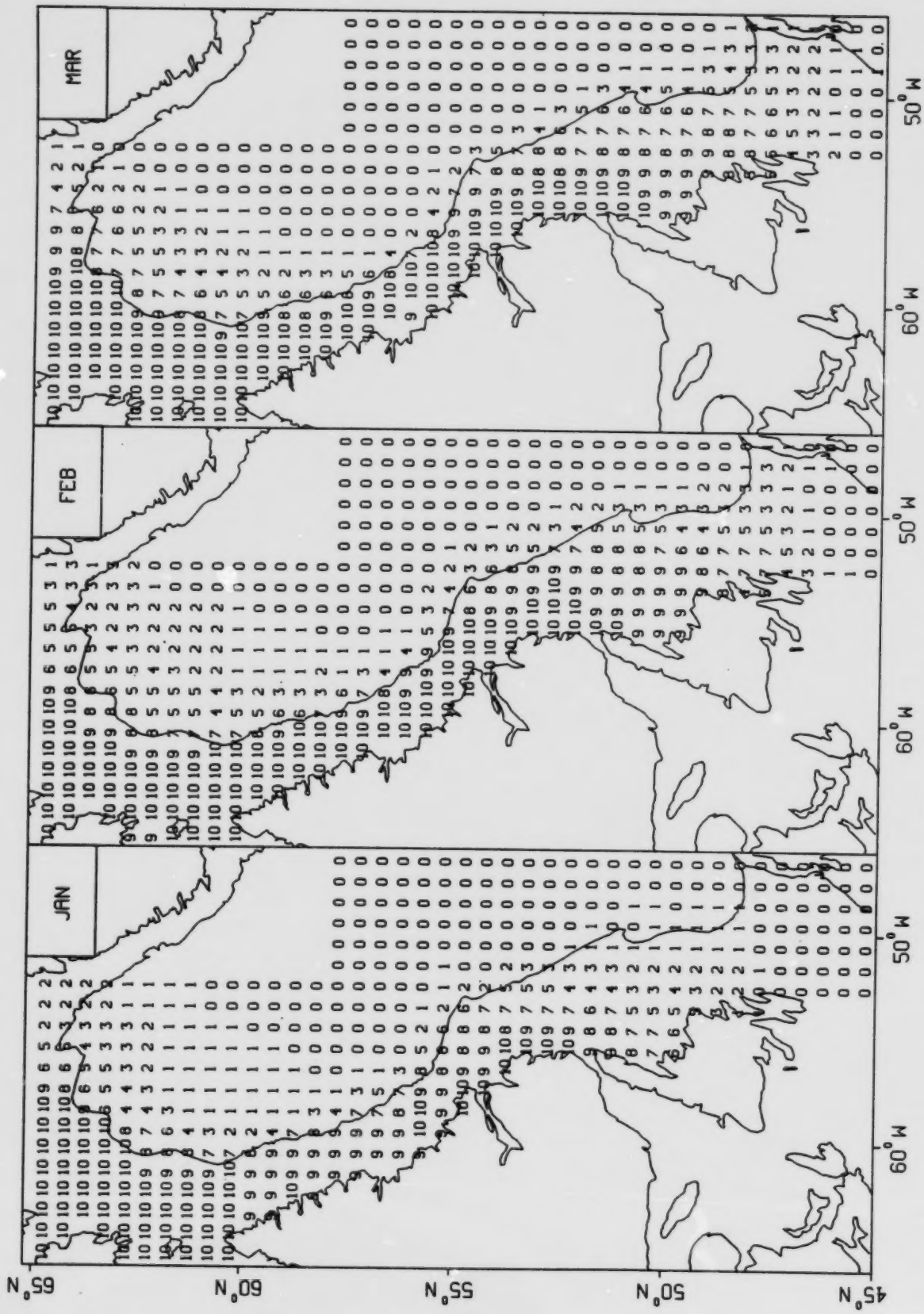


Figure 9. Mean geostrophic wind components (December - February), 1946-1988. The year refers to February. The crosses refer to the northwest component (positive from the northwest), while the circles refer to the southwest component (positive from the southwest).

APPENDIX A

PROBABILITY OF ICE OCCURRENCE BY MONTH AND GRID SQUARE

The number in the each grid square represents the probability (x 10) of ice being observed in that square during the month, and was computed from data between 1963 and 1987. The 1000 m isobath is also plotted for reference.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55°N
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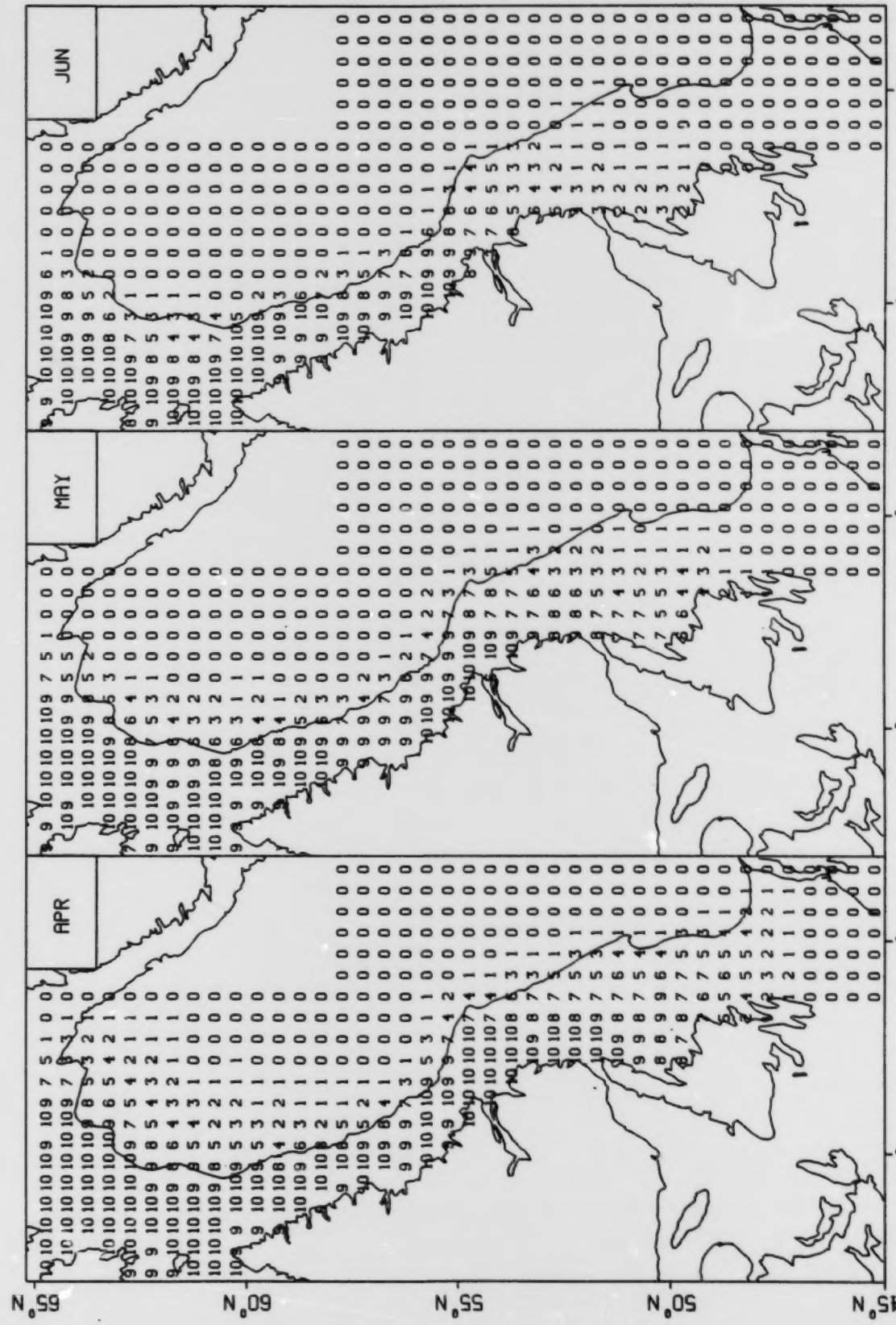
45°N
60°W
50°W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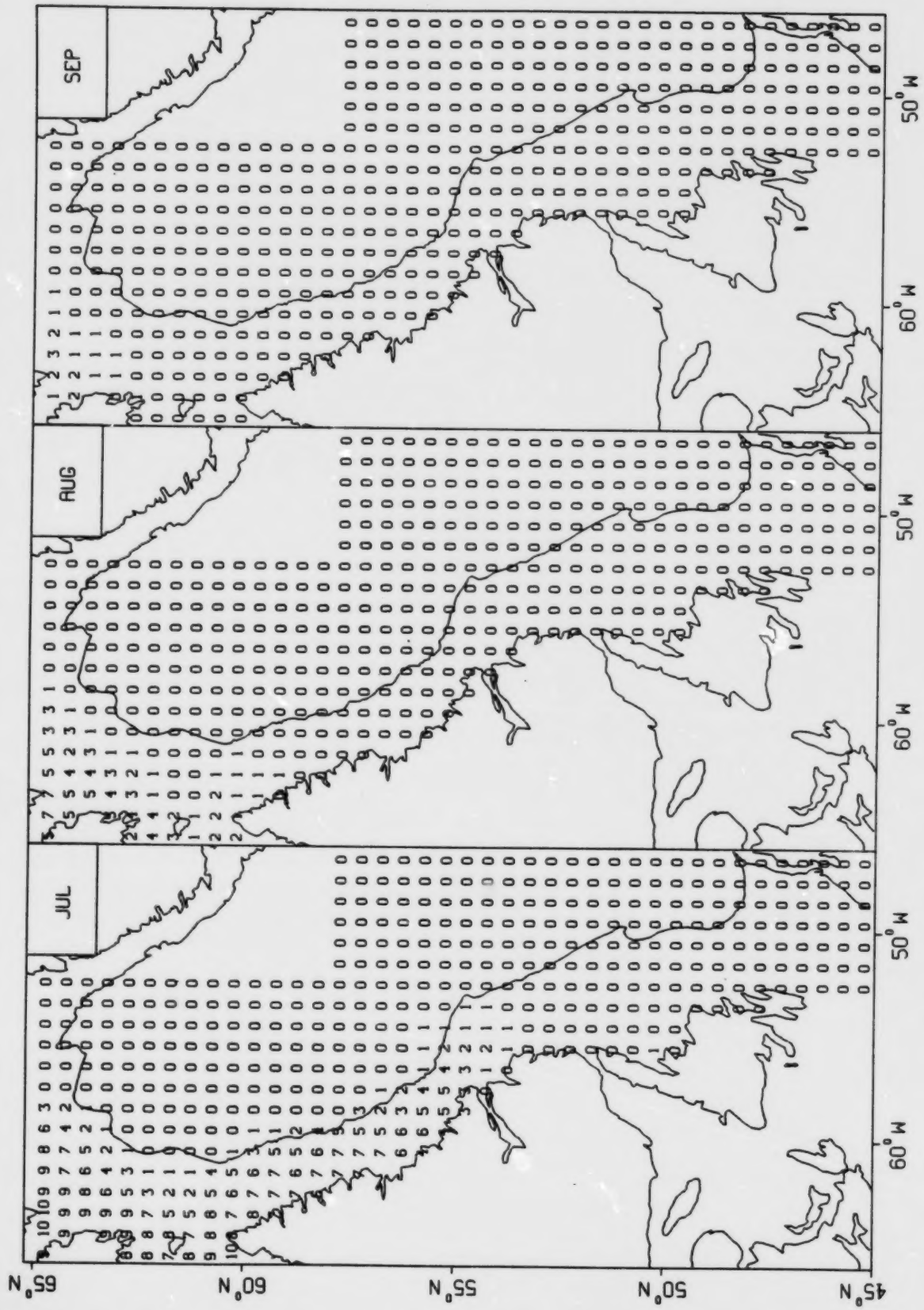
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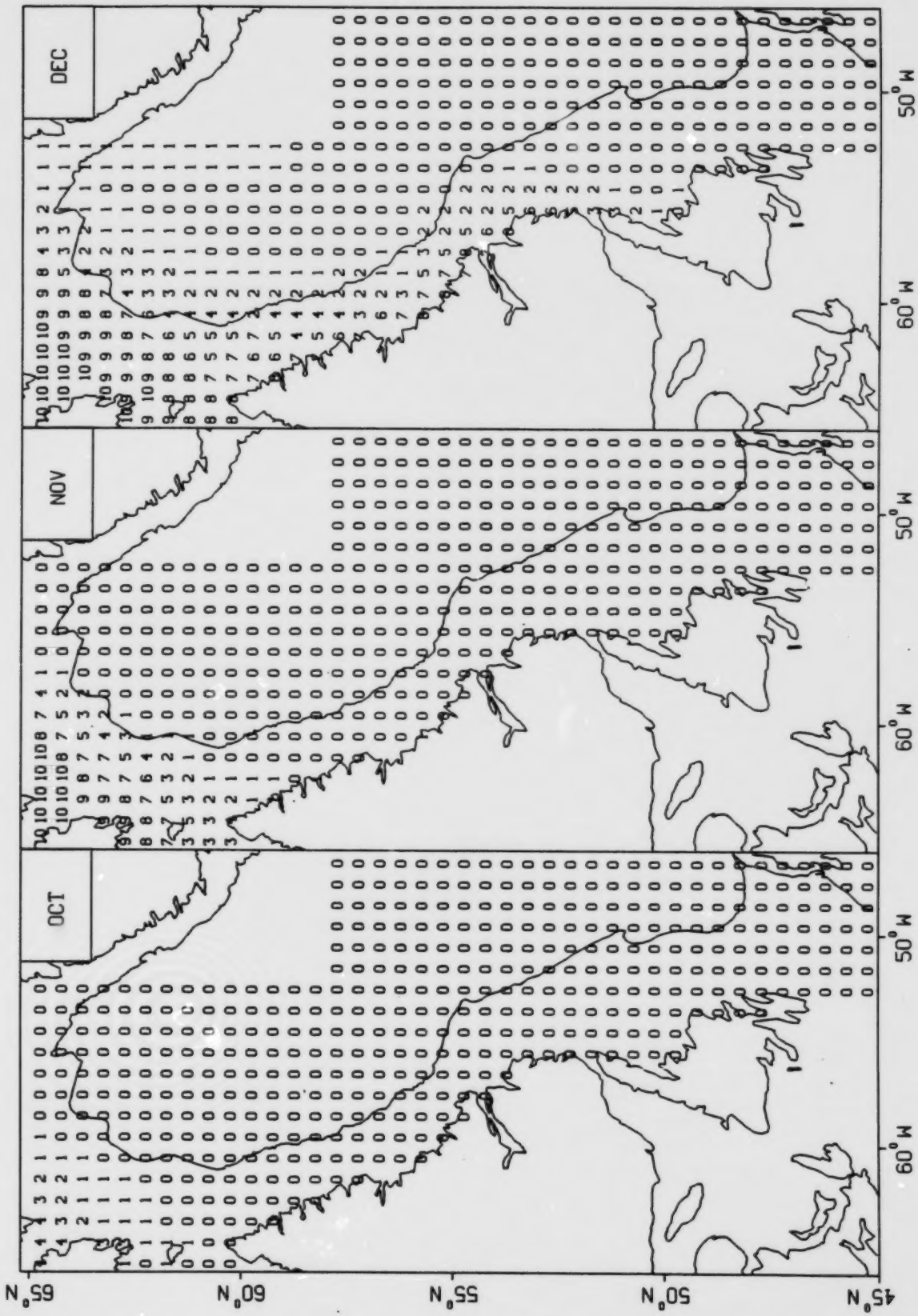
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OCT
65°N
60°N
55°N
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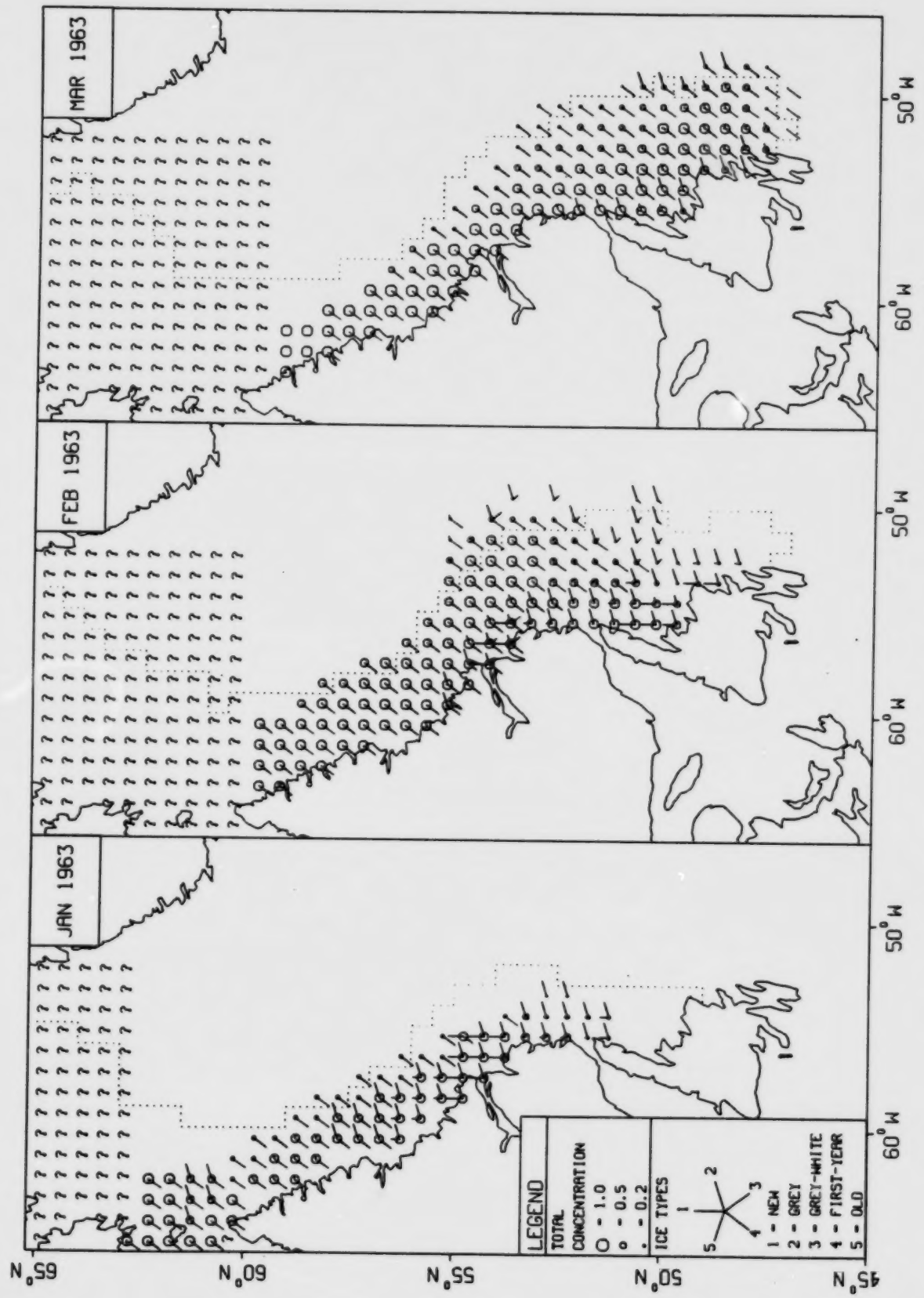
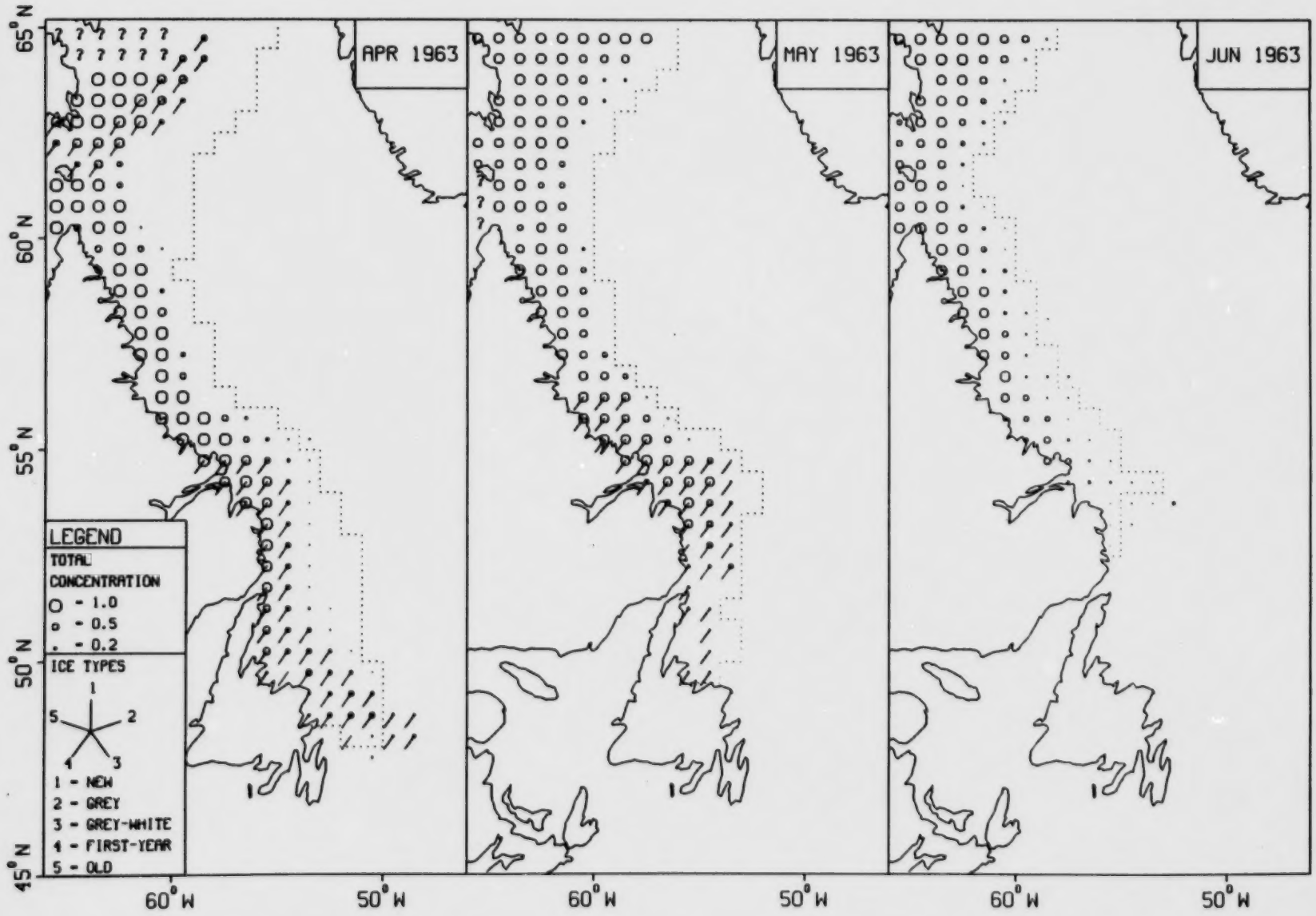
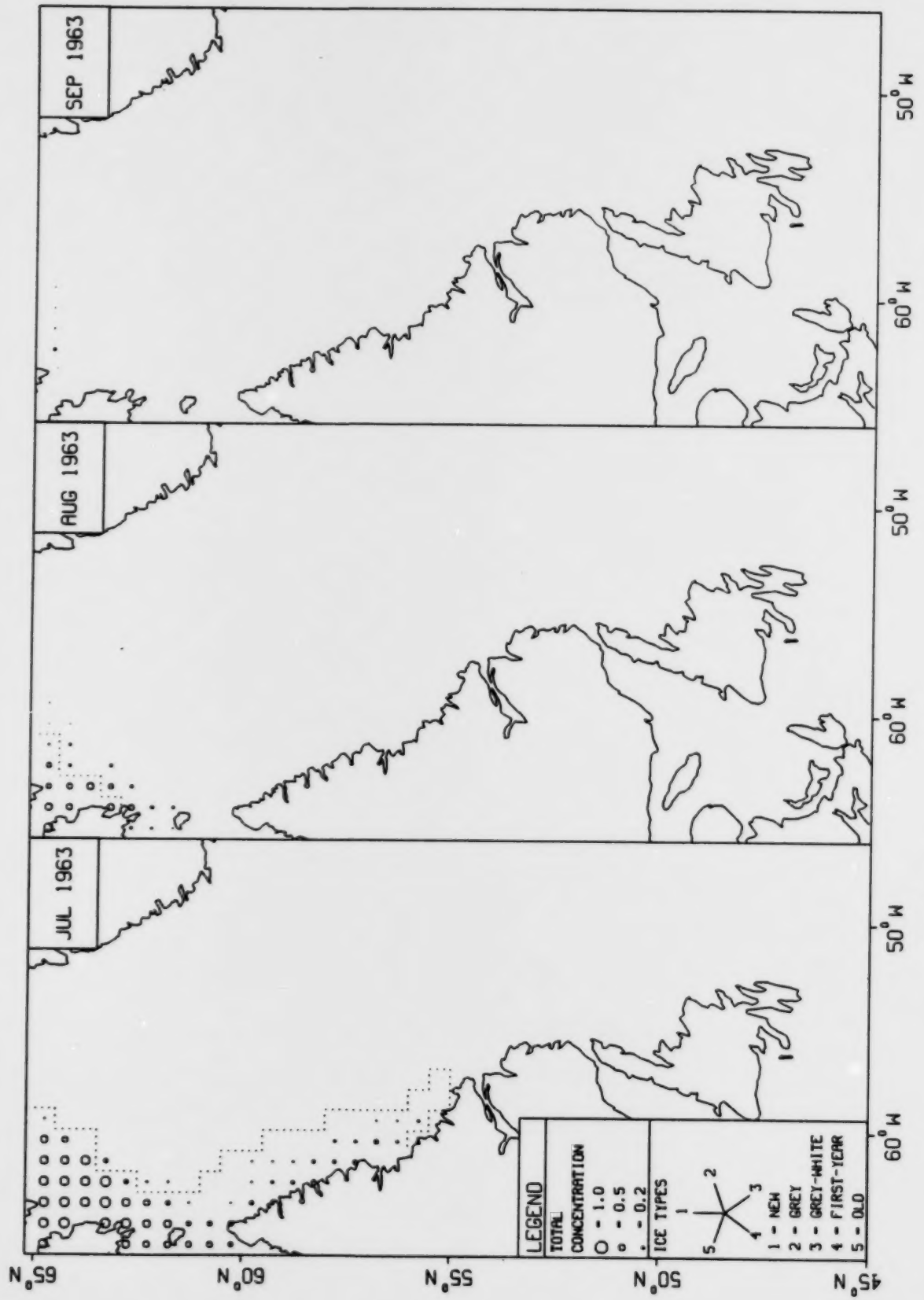
APPENDIX B

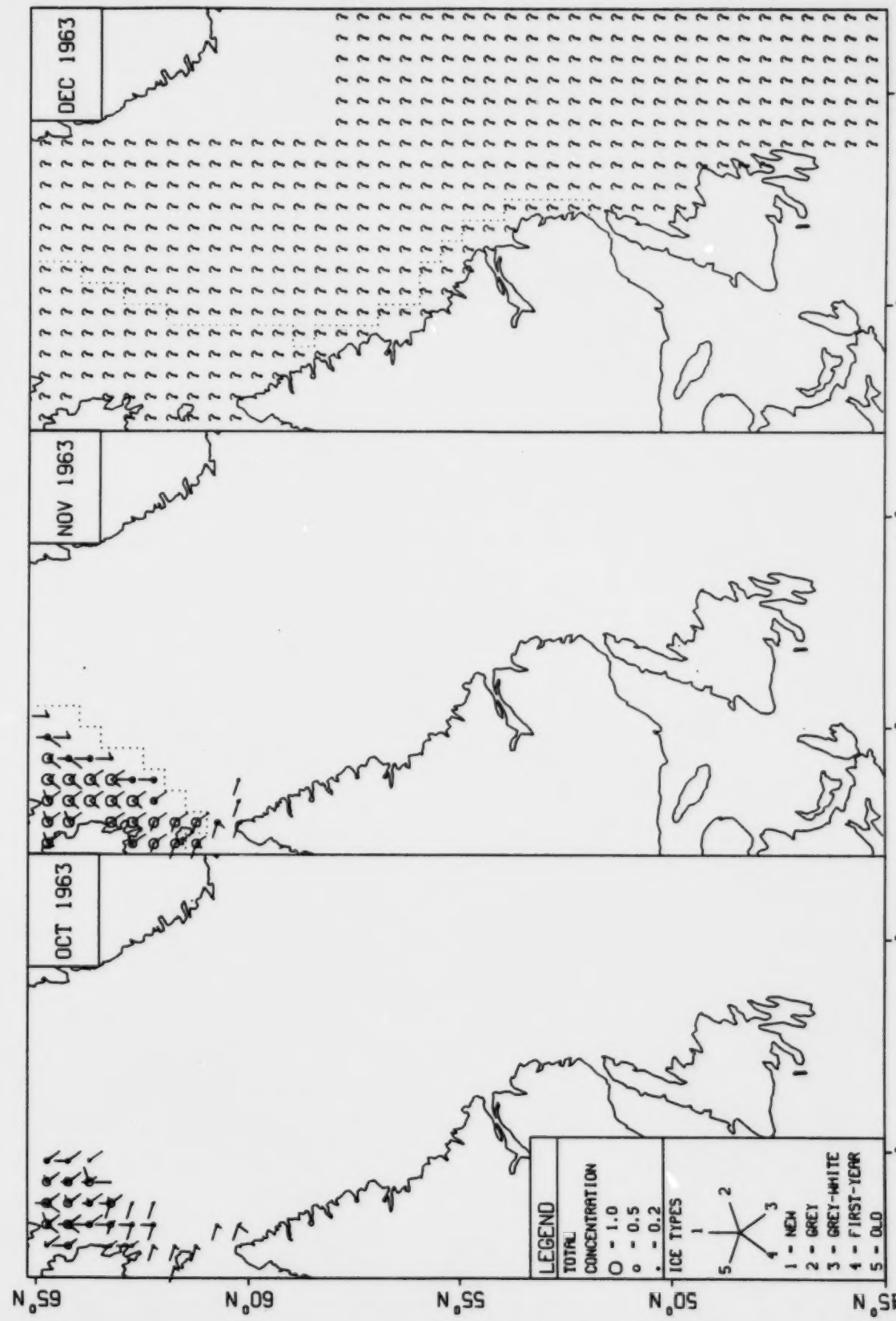
MONTHLY ICE CHARTS

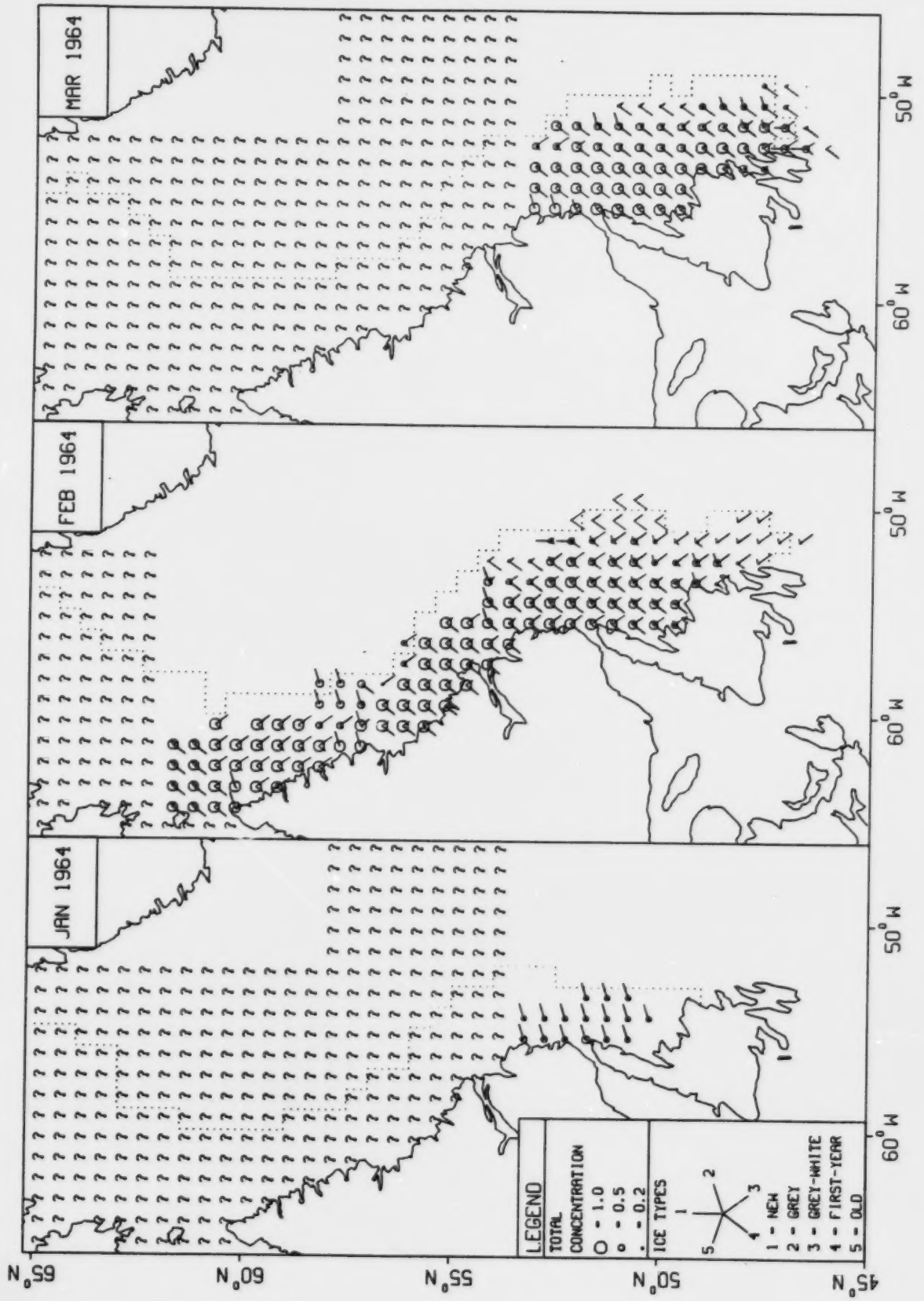
Charts show the mean monthly total ice concentration, and the relative concentrations of the various ice types, for the period 1963 to 1988. The dotted line in each chart represents the 25 year median ice edge (1963-1987) for the given month. The median ice edge represents the limit of grid cells where ice was present during the month in at least 50% of the years, 1963-1987. For the charts for 1979-1988, the data set used contains no ice concentration data east of the dashed line.


JAN 1963
FEB 1963
MAR 1963
LEGEND
TOTAL
CONCENTRATION
○ - 1.0
o - 0.5
. - 0.2
ICE TYPES
1 - NEW
2 - GREY
3 - GREY-WHITE
4 - FIRST-YEAR
5 - OLD
65°N
60°N
55°N
50°N
45°N
60°W
50°W


APR 1963
MAY 1963
JUN 1963
65°N
60°N
55°N
50°N
45°N
60°W
50°W
LEGEND
TOTAL CONCENTRATION
○ - 1.0
o - 0.5
. - 0.2
ICE TYPES
1
2
3
4
5
1 - NEW
2 - GREY
3 - GREY-WHITE
4 - FIRST-YEAR
5 - OLD


SEP 1963
AUG 1963
JUL 1963
LEGEND
TOTAL
CONCENTRATION
O - 1.0
o - 0.5
. - 0.2
ICE TYPES
1 - NEW
2 - GREY
3 - GREY-WHITE
4 - FIRST-YEAR
5 - OLD
65°N
60°N
55°N
50°N
45°N
60°W
50°W


OCT 1963
NOV 1963
DEC 1963
LEGEND
TOTAL CONCENTRATION
O - 1.0
o - 0.5
. - 0.2
ICE TYPES
1 - NEW
2 - GREY
3 - GREY-WHITE
4 - FIRST-YEAR
5 - OLD
65°N
60°N
55°N
50°N
45°N
60°W
50°W


JAN 1964
FEB 1964
MAR 1964
LEGEND
TOTAL CONCENTRATION
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ICE TYPES
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2 - GREY
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4 - FIRST-YEAR
5 - OLD
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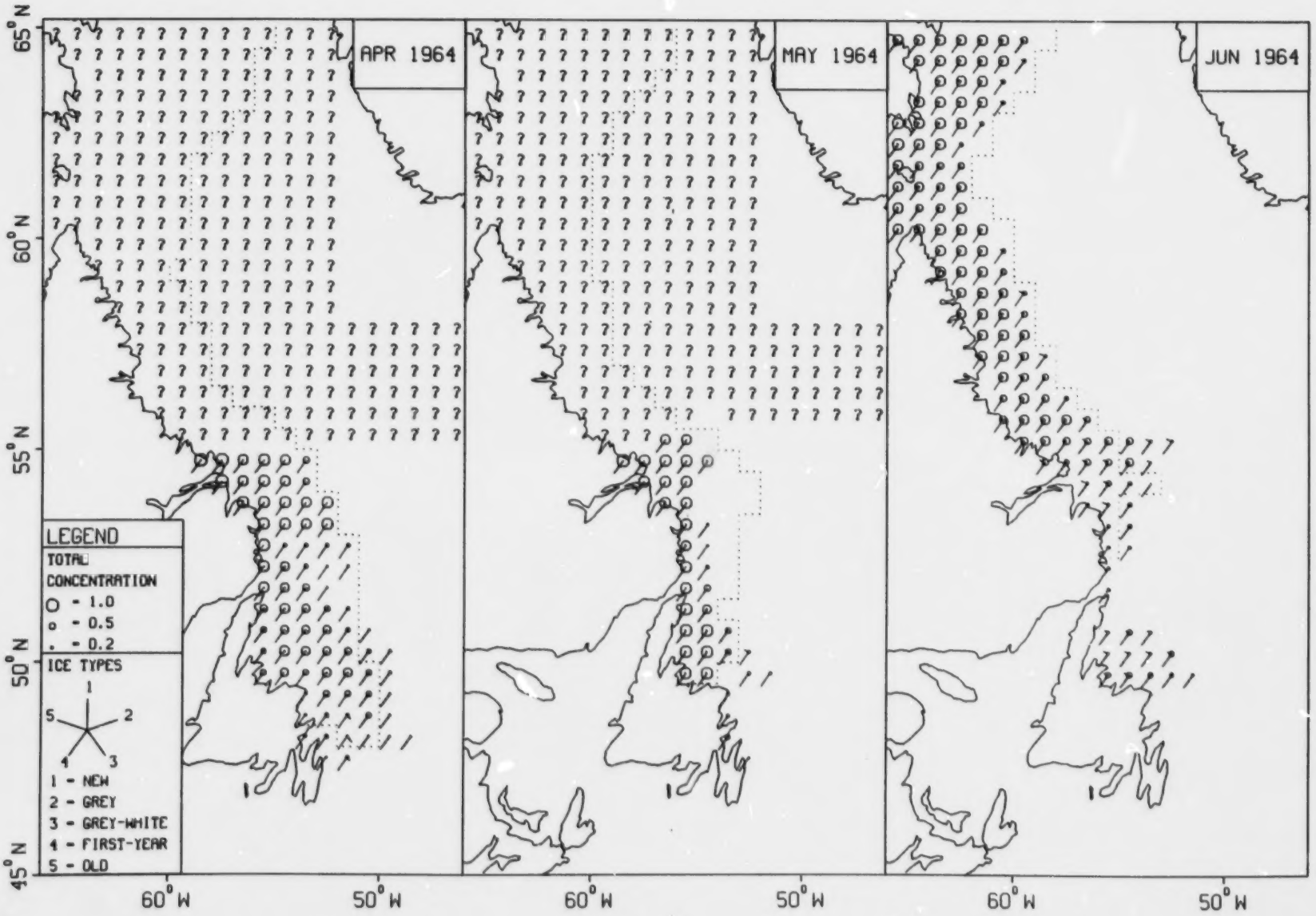
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55°N
50°N
45°N
60°W
50°W
LEGEND
TOTAL CONCENTRATION
O - 1.0
o - 0.5
. - 0.2
ICE TYPES
1
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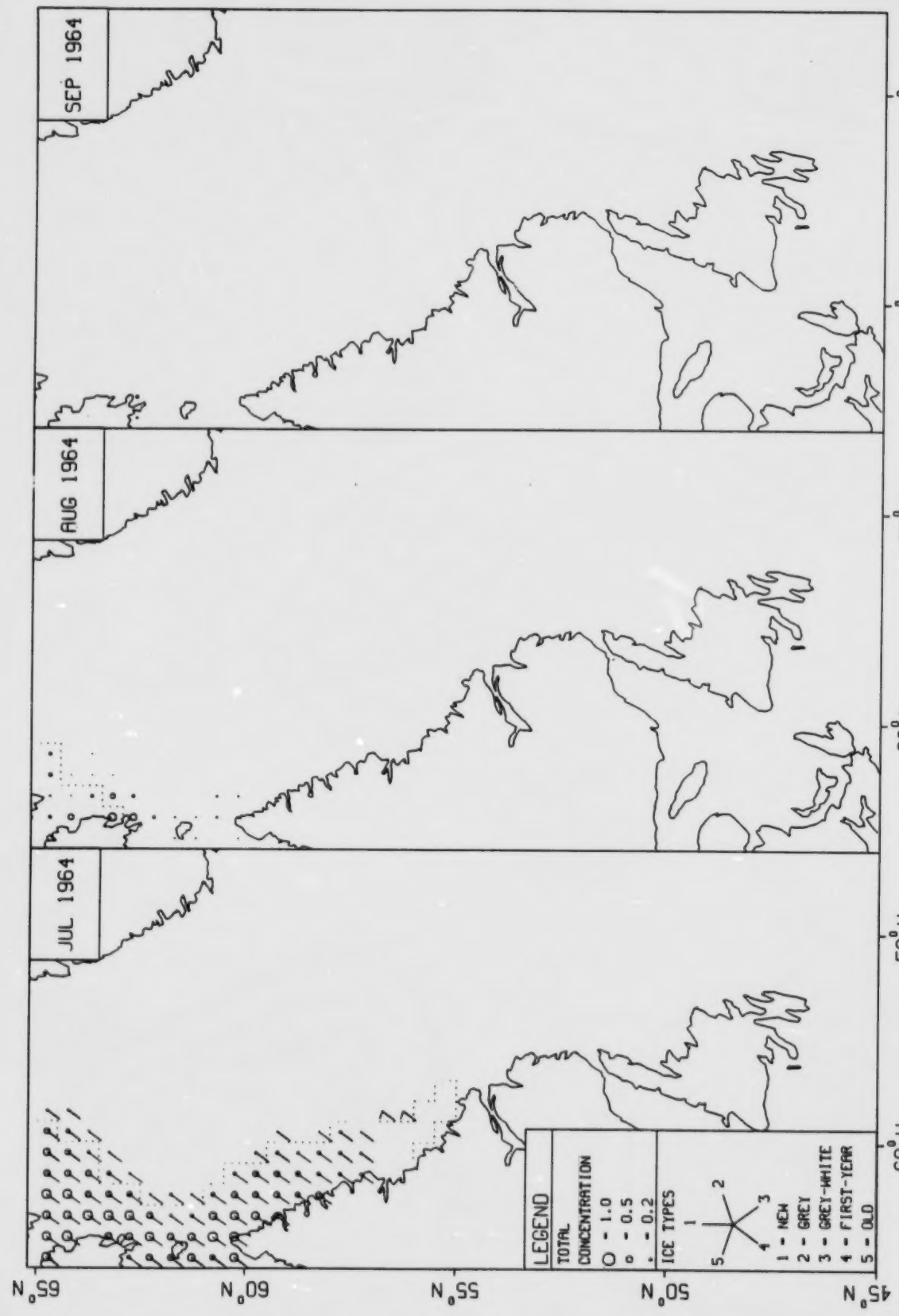
3
4
5
1 - NEW
2 - GREY
3 - GREY-WHITE
4 - FIRST-YEAR
5 - OLD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LEGEND
TOTAL
CONCENTRATION
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o - 0.5
. - 0.2
ICE TYPES
1 - NEW
2 - GREY
3 - GREY-WHITE
4 - FIRST-YEAR
5 - OLD
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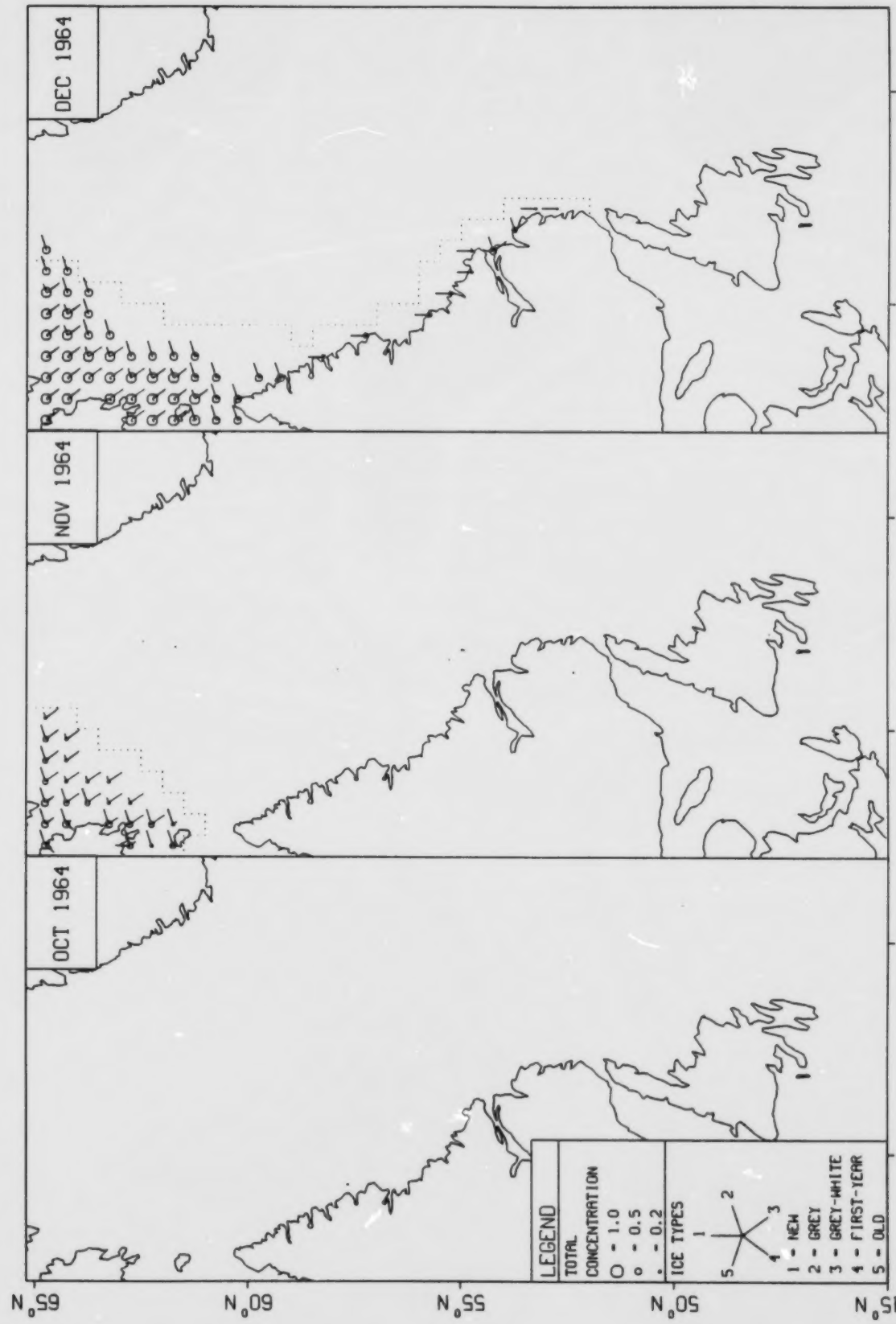
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TOTAL
CONCENTRATION
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. - 0.2
ICE TYPES
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2 - GREY
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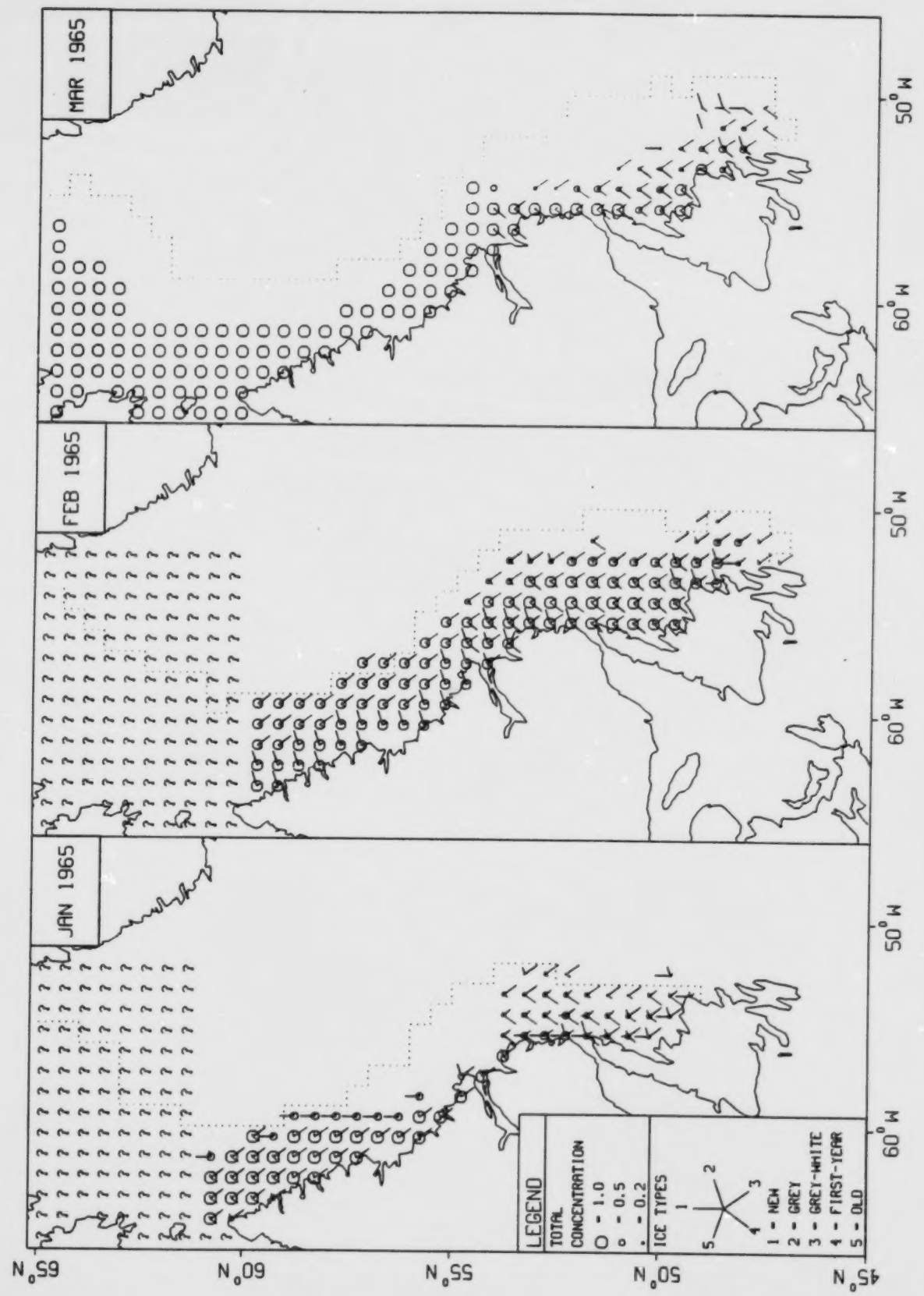
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FEB 1965
JAN 1965
LEGEND
TOTAL CONCENTRATION
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o - 0.5
. - 0.2
ICE TYPES
1 - NEW
2 - GREY
3 - GREY-WHITE
4 - FIRST-YEAR
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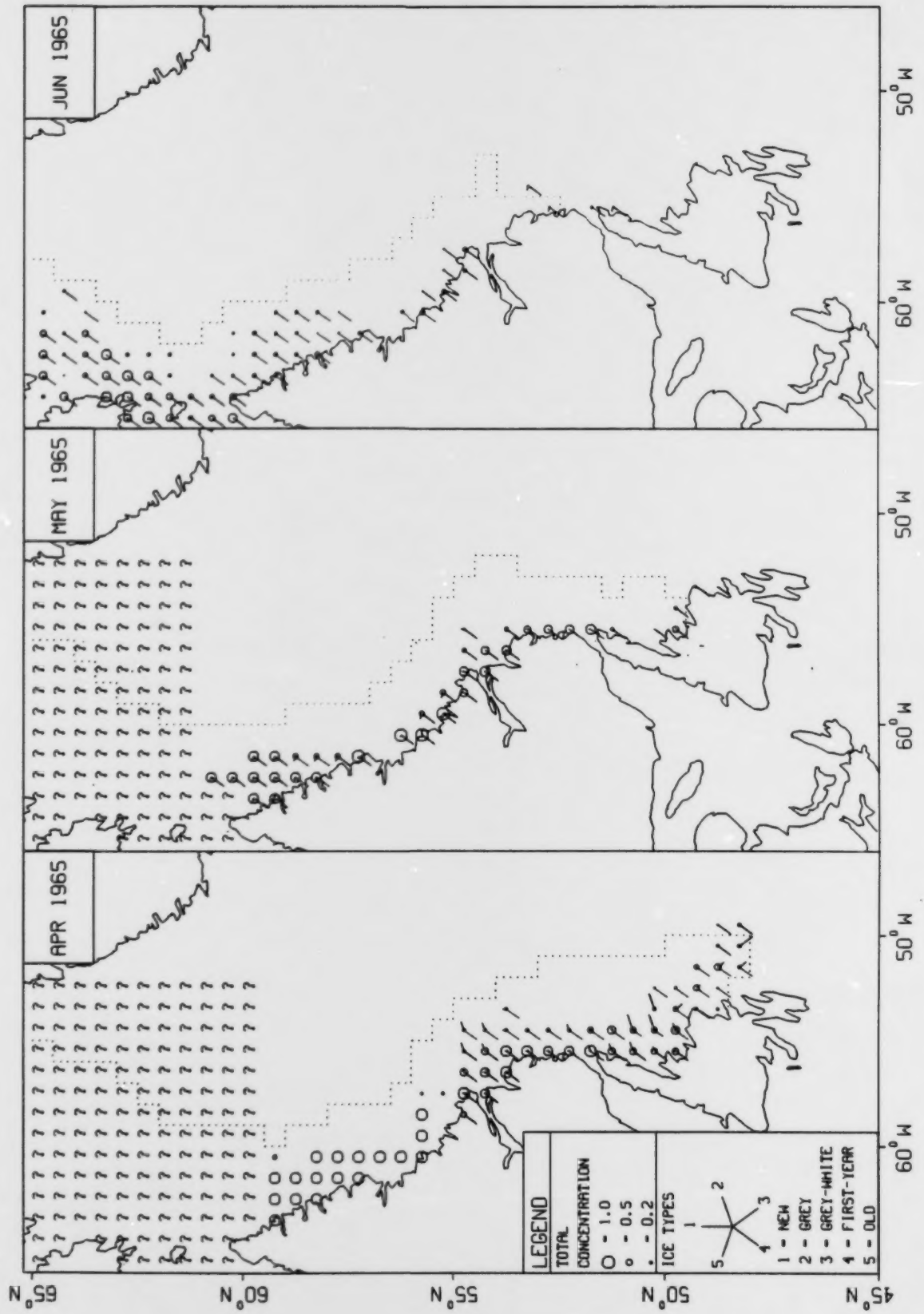
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LEGEND
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. - 0.2
ICE TYPES
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2 - GREY
3 - GREY-WHITE
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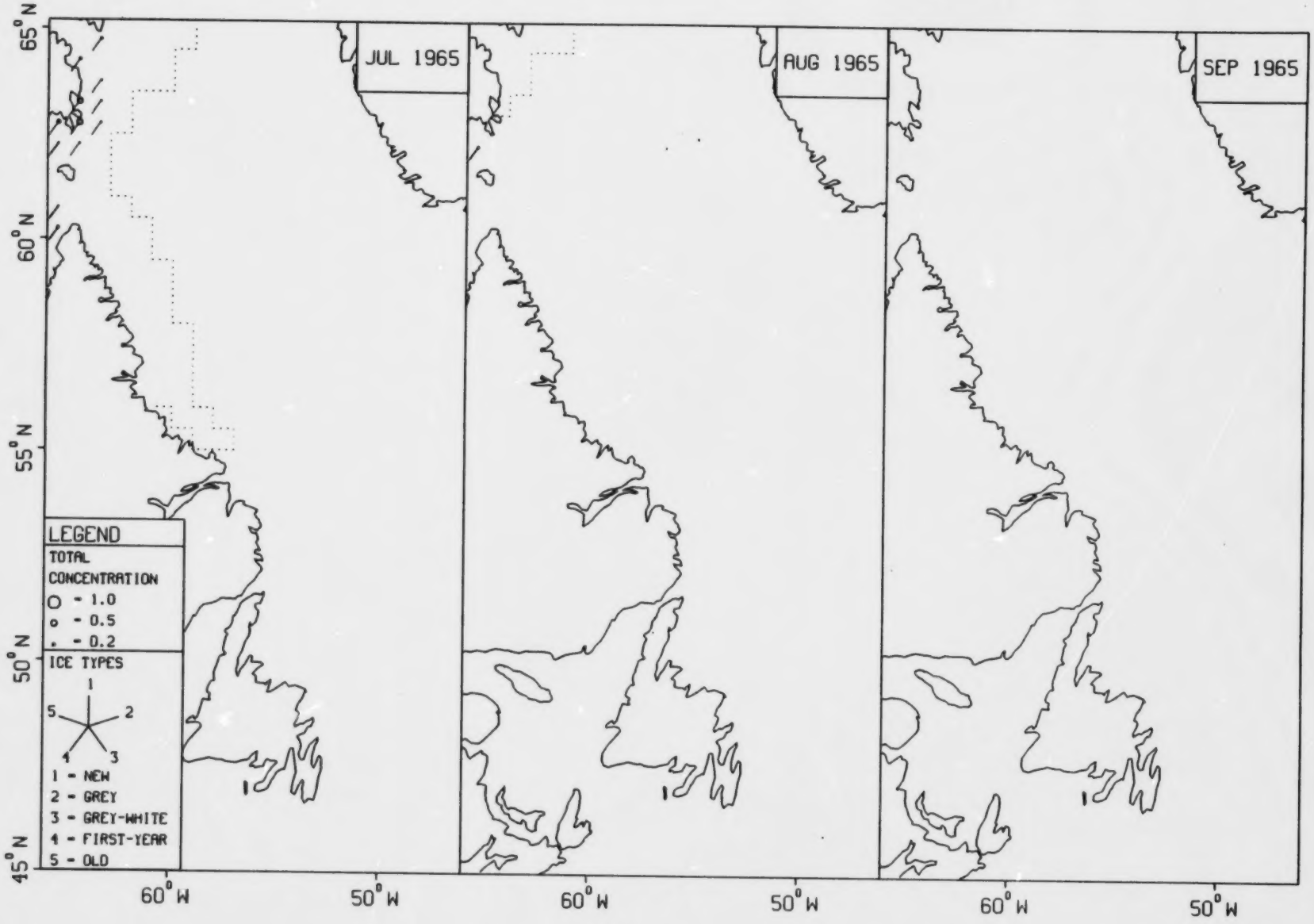
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LEGEND
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CONCENTRATION
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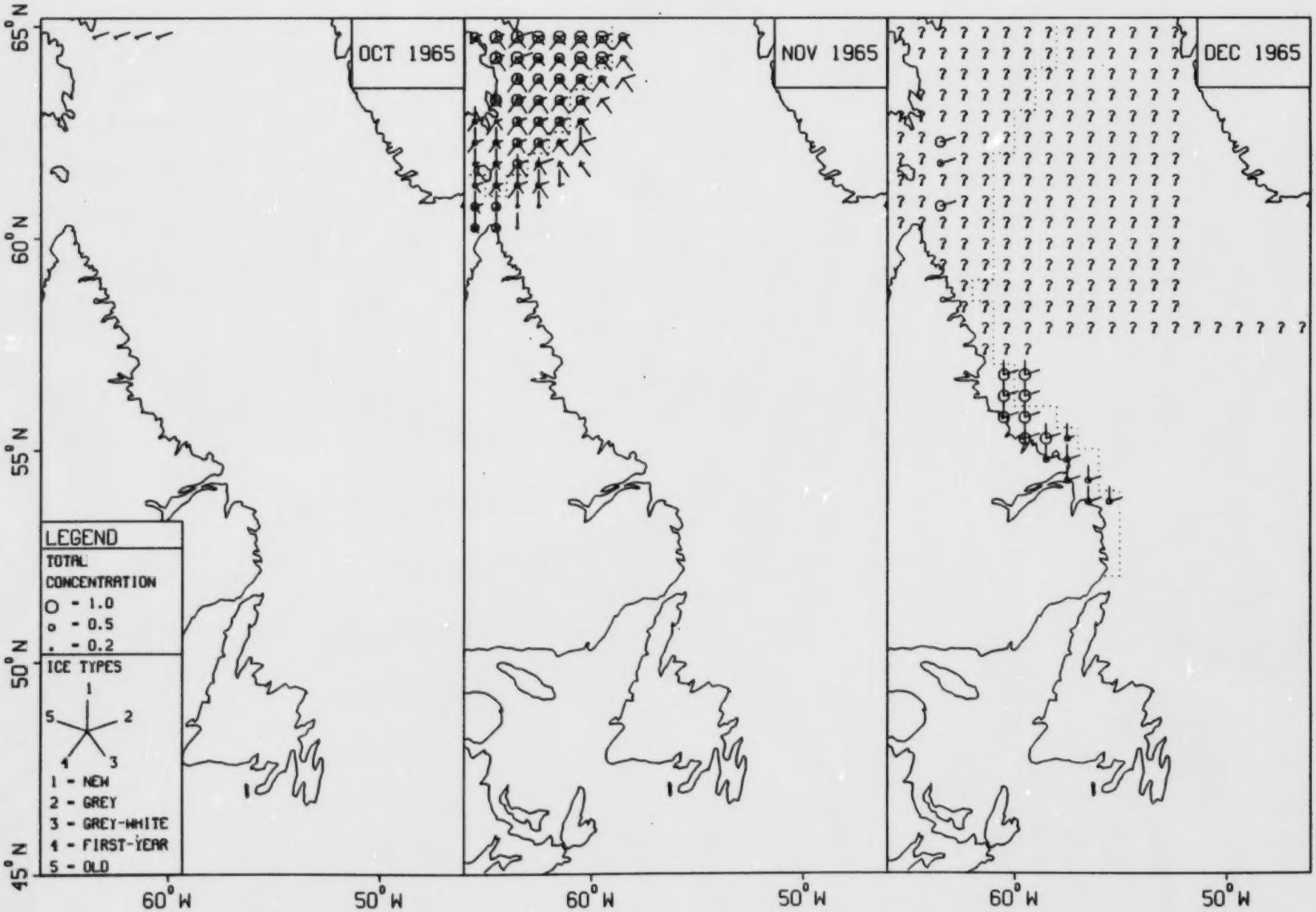
5 - OLD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LEGEND
TOTAL
CONCENTRATION
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ICE TYPES
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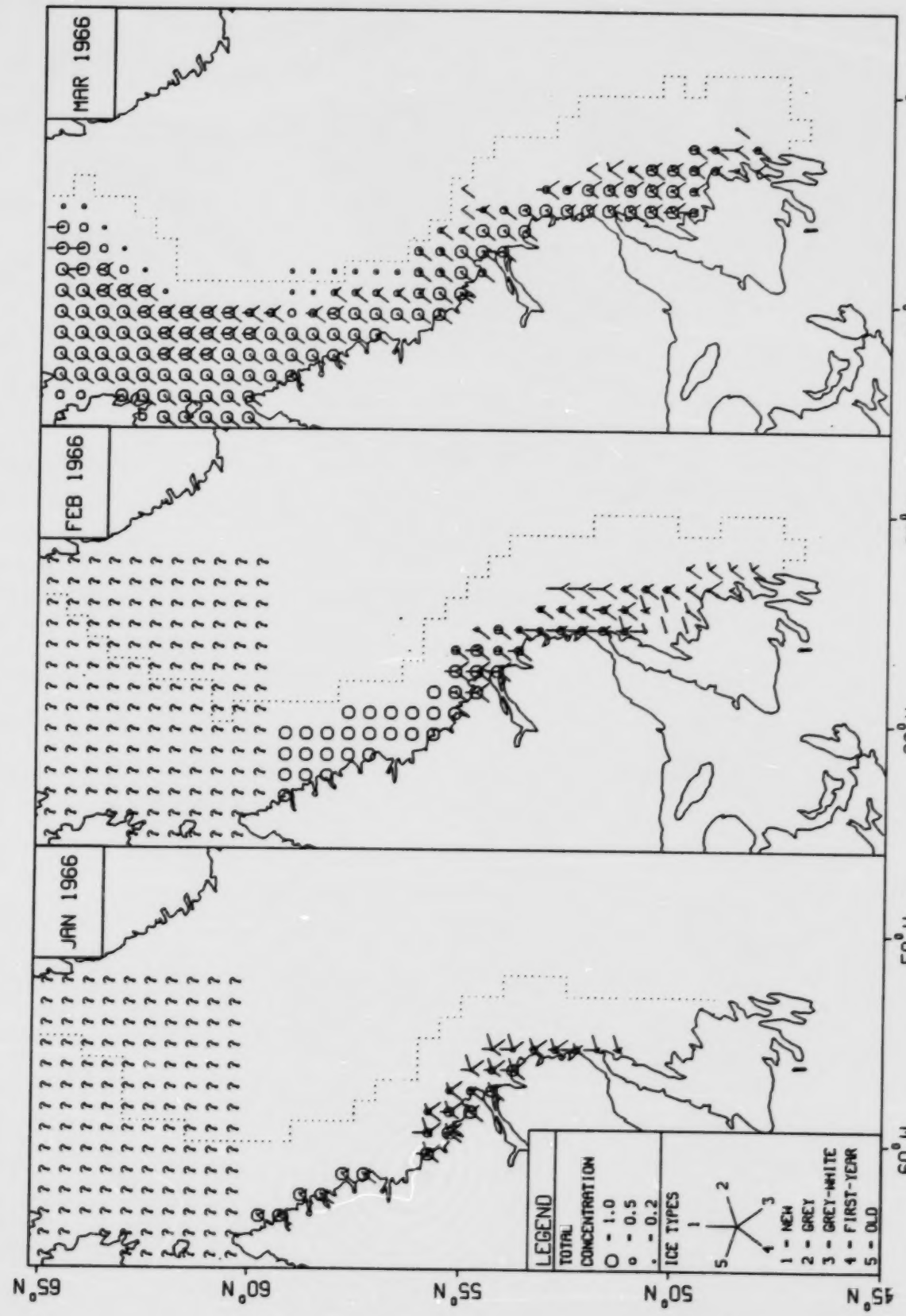
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LEGEND
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ICE TYPES
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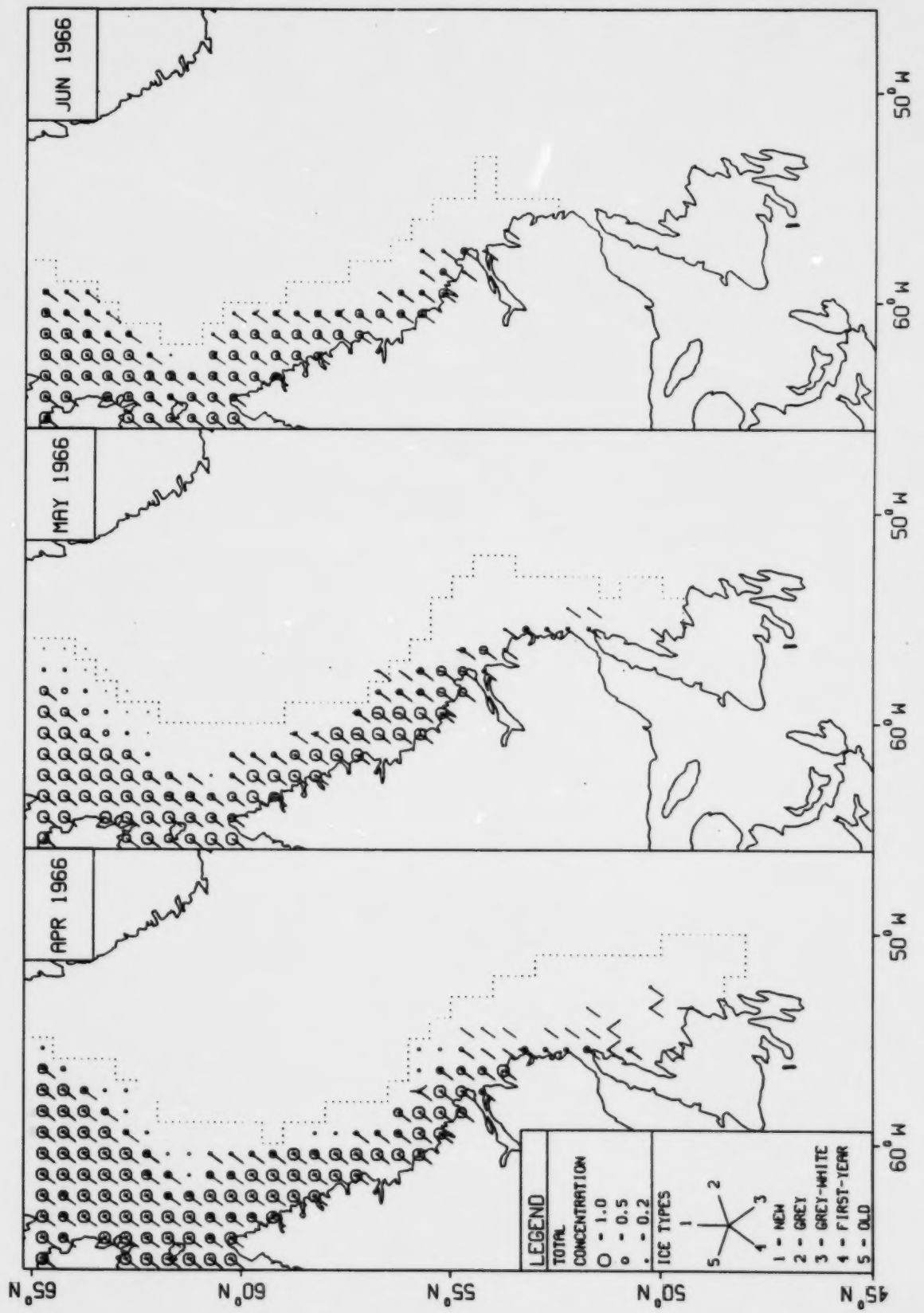
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JUN 1966
LEGEND
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ICE TYPES
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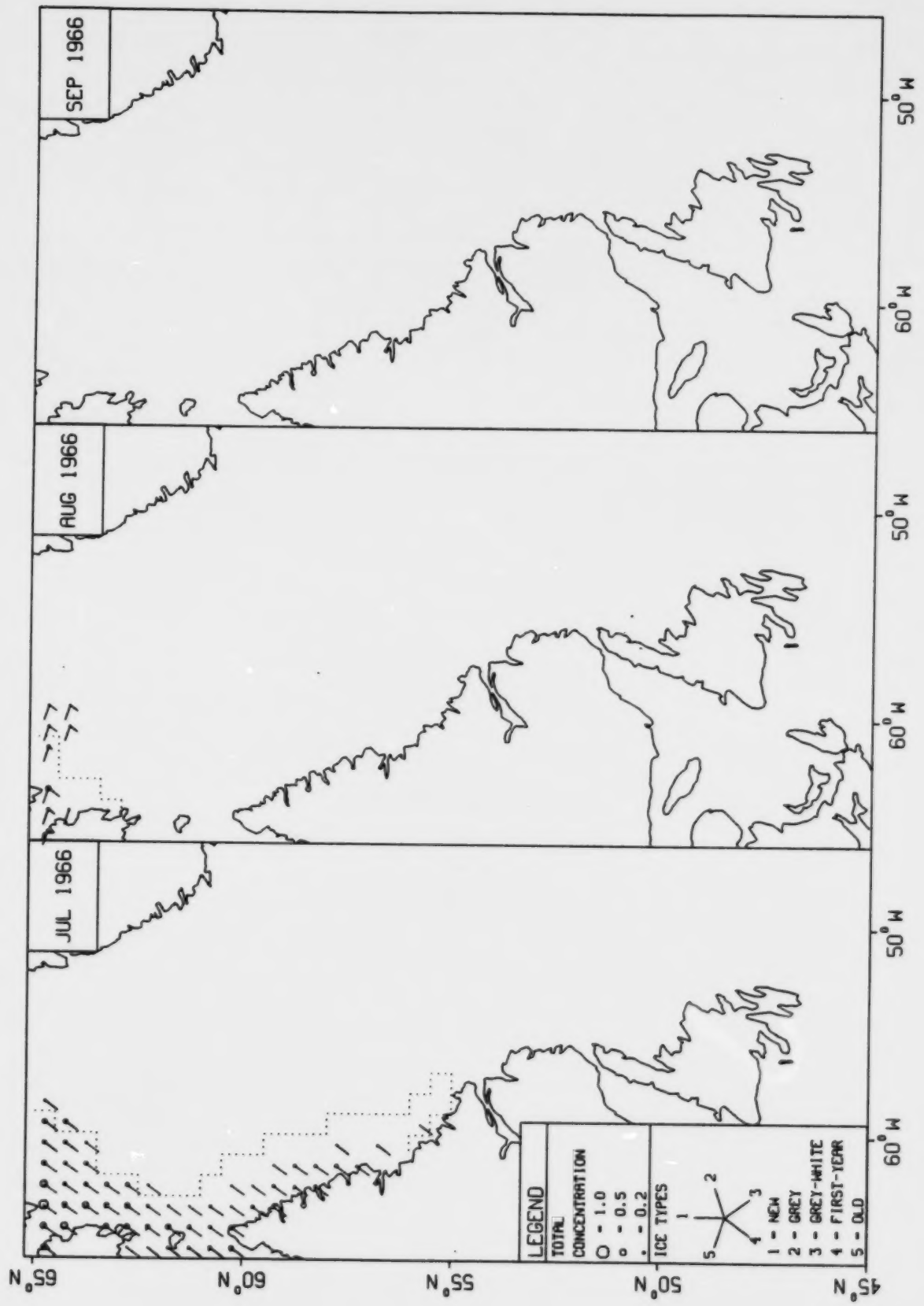
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ICE TYPES
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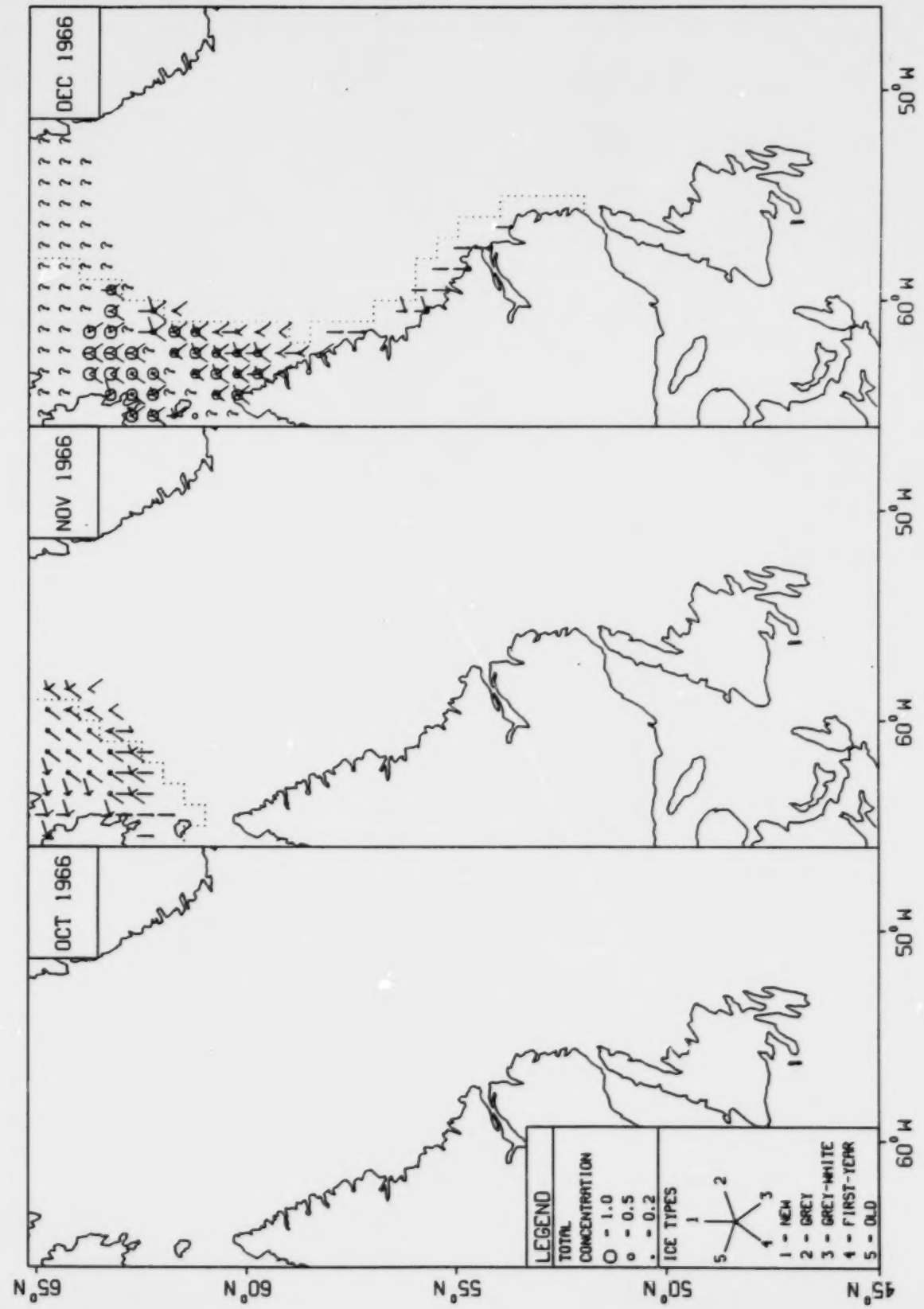
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ICE TYPES
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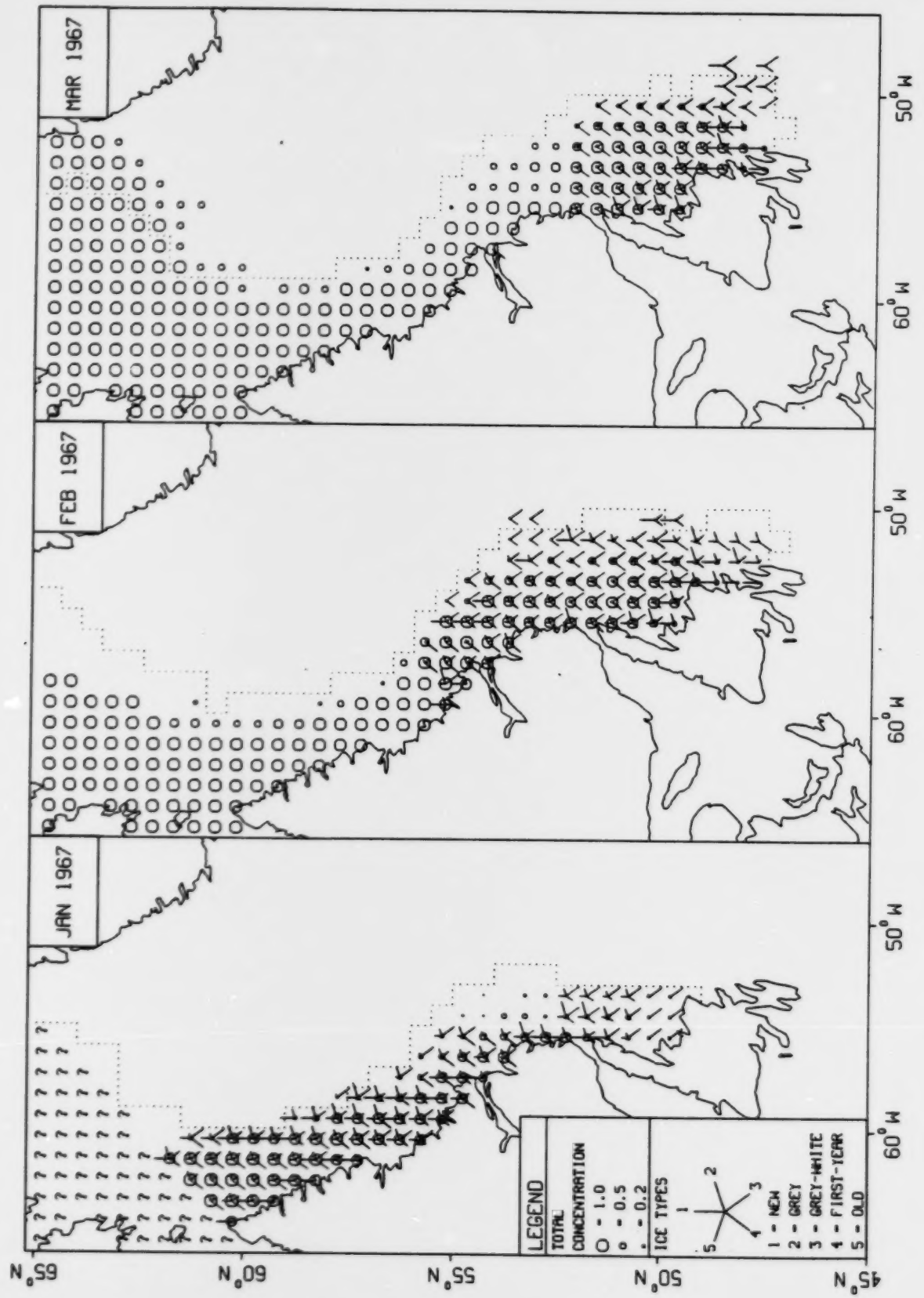
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FEB 1967
MAR 1967
LEGEND
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CONCENTRATION
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ICE TYPES
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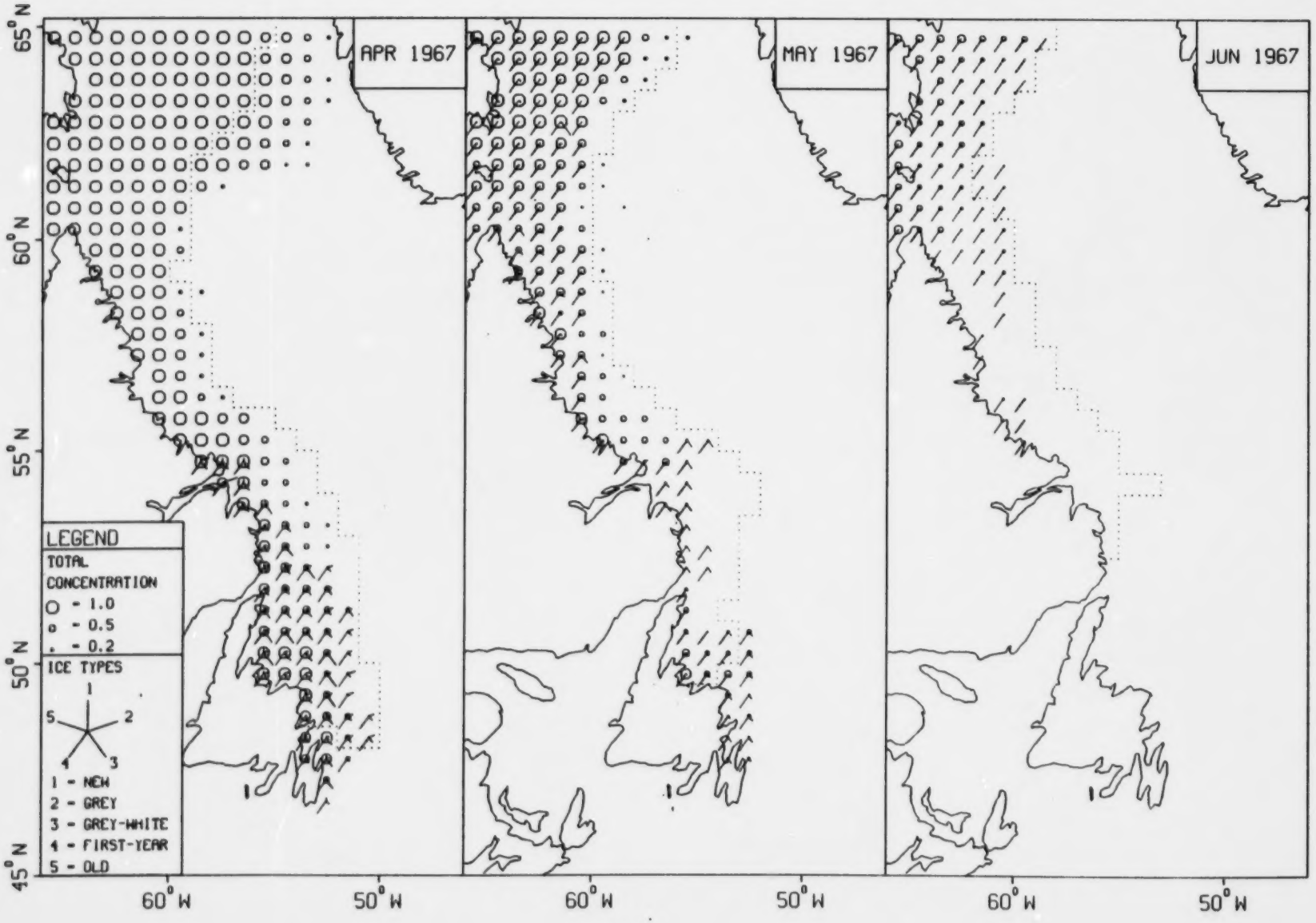
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MAY 1967
JUN 1967
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LEGEND
TOTAL CONCENTRATION
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ICE TYPES
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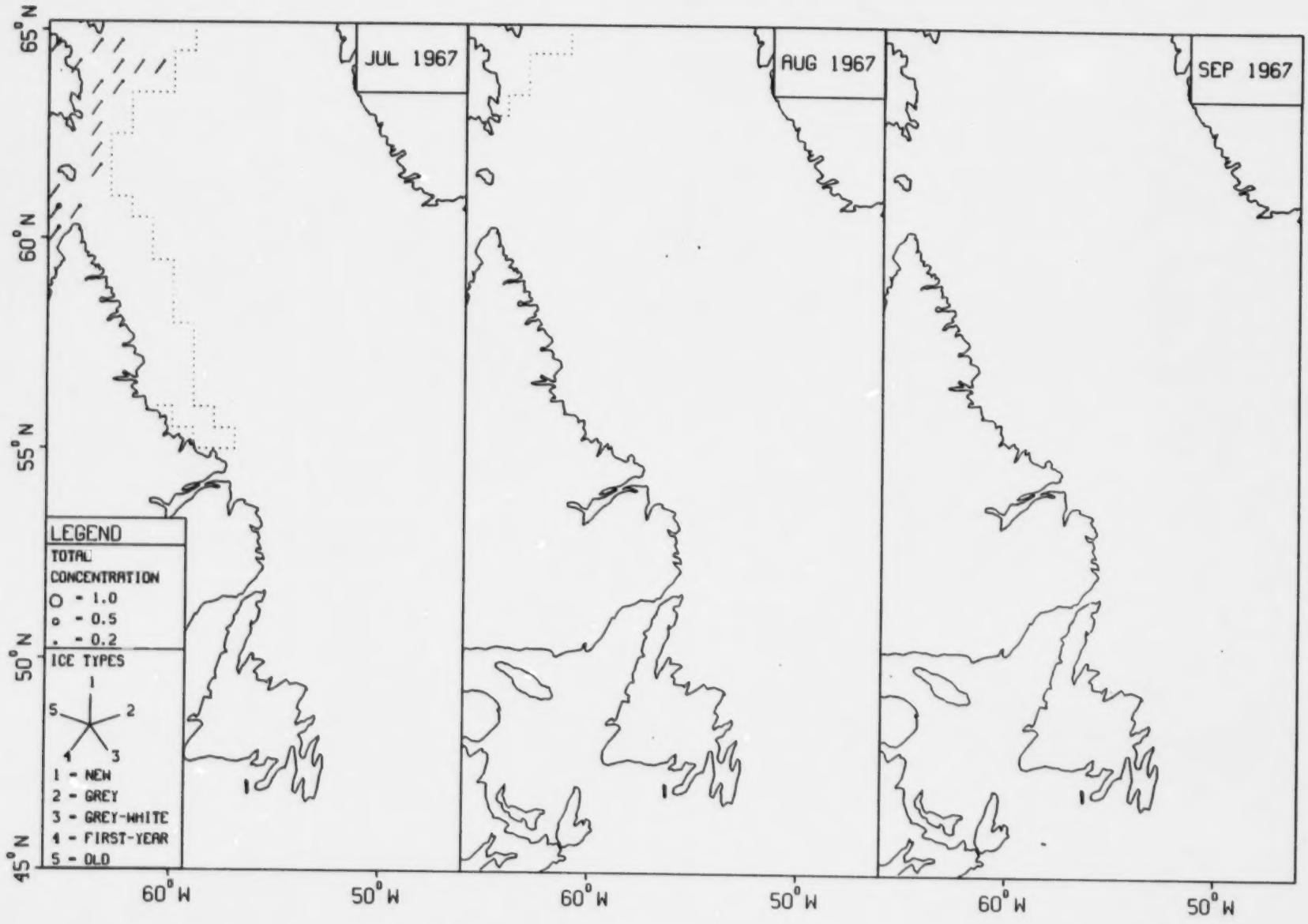
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AUG 1967
SEP 1967
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55°N
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45°N
60°W
50°W
LEGEND
TOTAL CONCENTRATION
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ICE TYPES
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3 - GREY-WHITE
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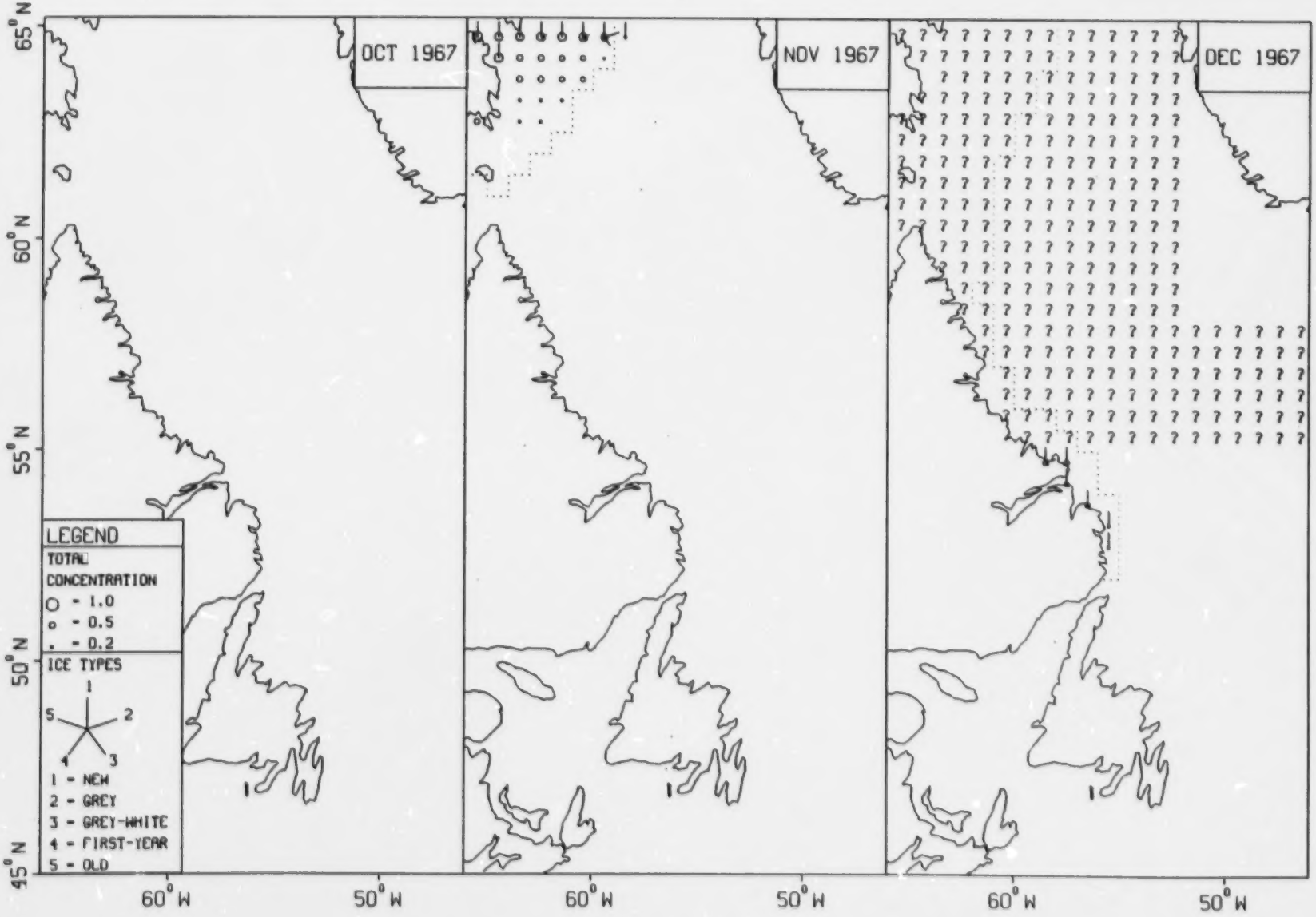
OCT 1967
NOV 1967
DEC 1967
65°N
60°N
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50°N
45°N
60°W
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LEGEND
TOTAL CONCENTRATION
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. - 0.2
ICE TYPES
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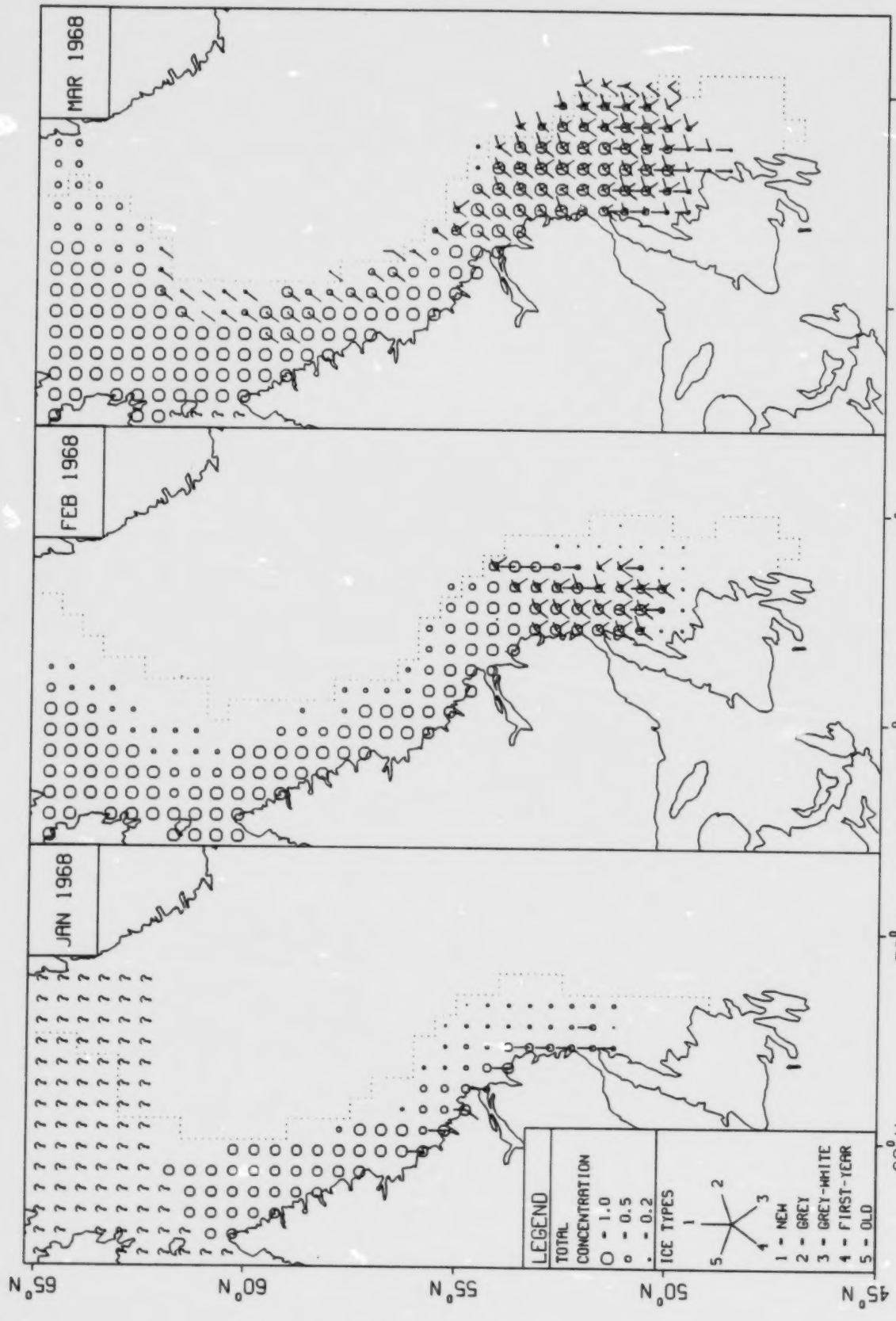
2 - GREY
3 - GREY-WHITE
4 - FIRST-YEAR
5 - OLD


JAN 1968
FEB 1968
MAR 1968
LEGEND
TOTAL CONCENTRATION
○ - 1.0
o - 0.5
. - 0.2
ICE TYPES
1 - NEW
2 - GREY
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4 - FIRST-YEAR
5 - OLD
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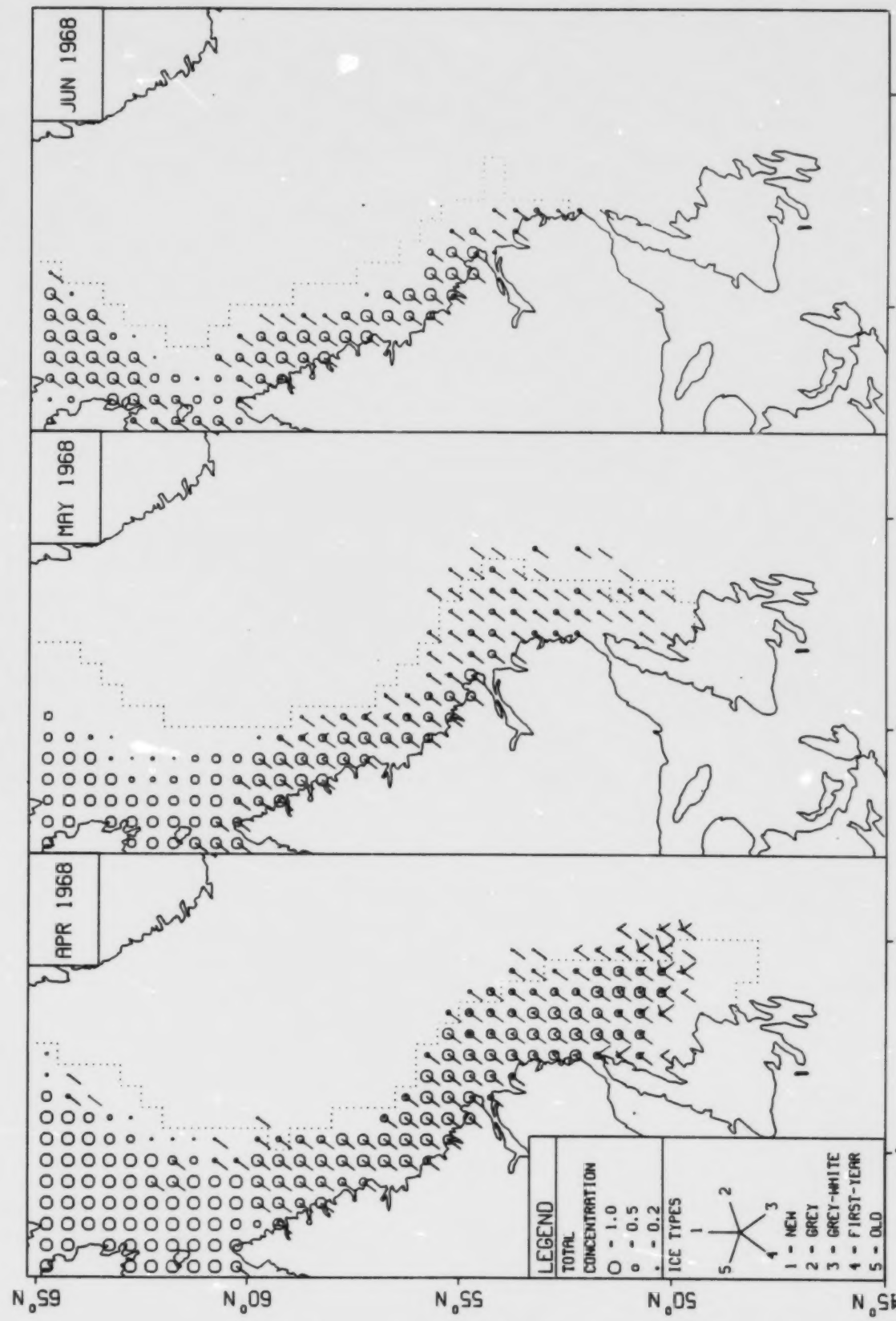
APR 1968
MAY 1968
JUN 1968
LEGEND
TOTAL CONCENTRATION
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ICE TYPES
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3 - GREY-WHITE
4 - FIRST-YEAR
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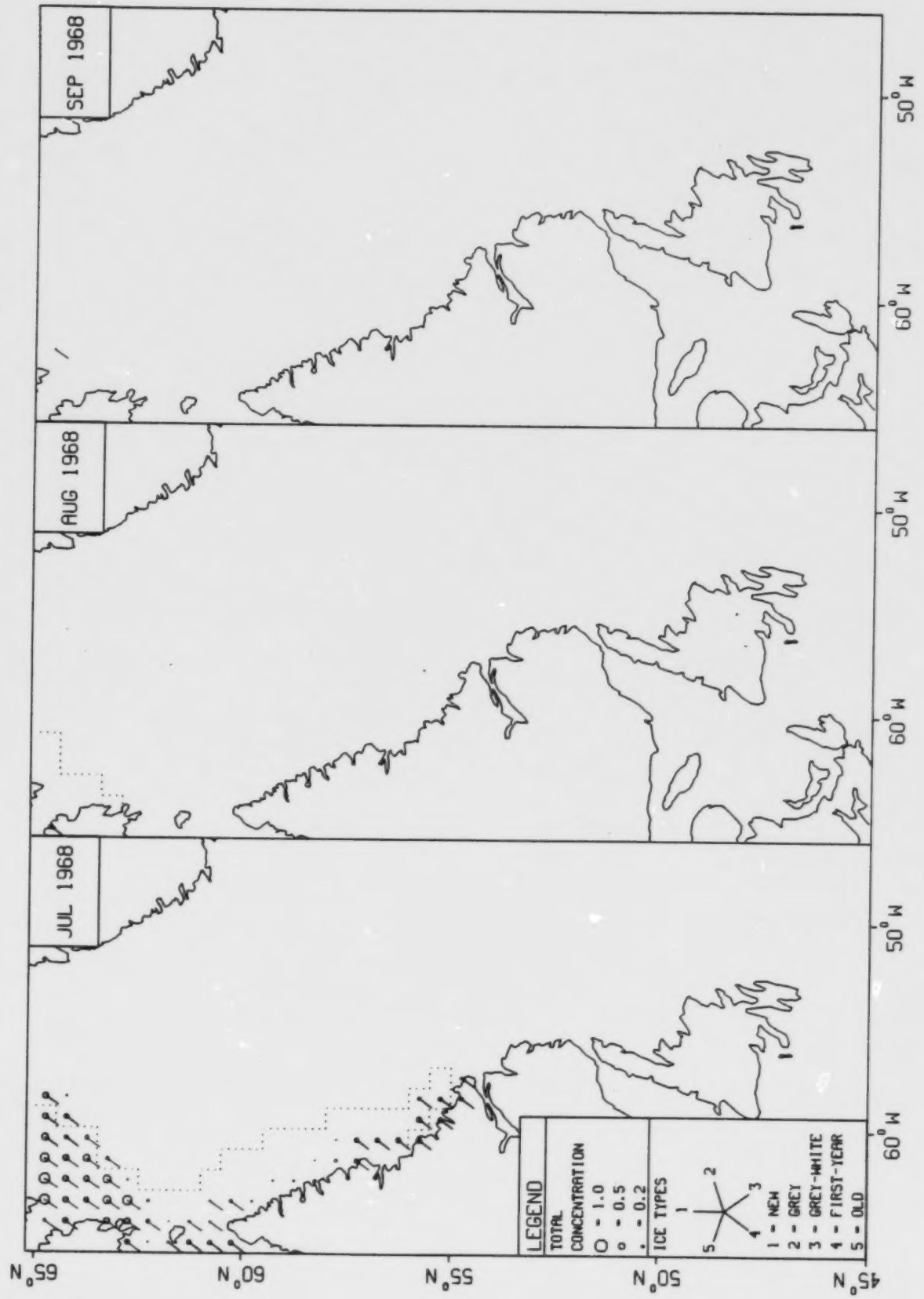
50°W


JUL 1968
AUG 1968
SEP 1968
LEGEND
TOTAL
CONCENTRATION
O - 1.0
o - 0.5
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ICE TYPES
1 - NEW
2 - GREY
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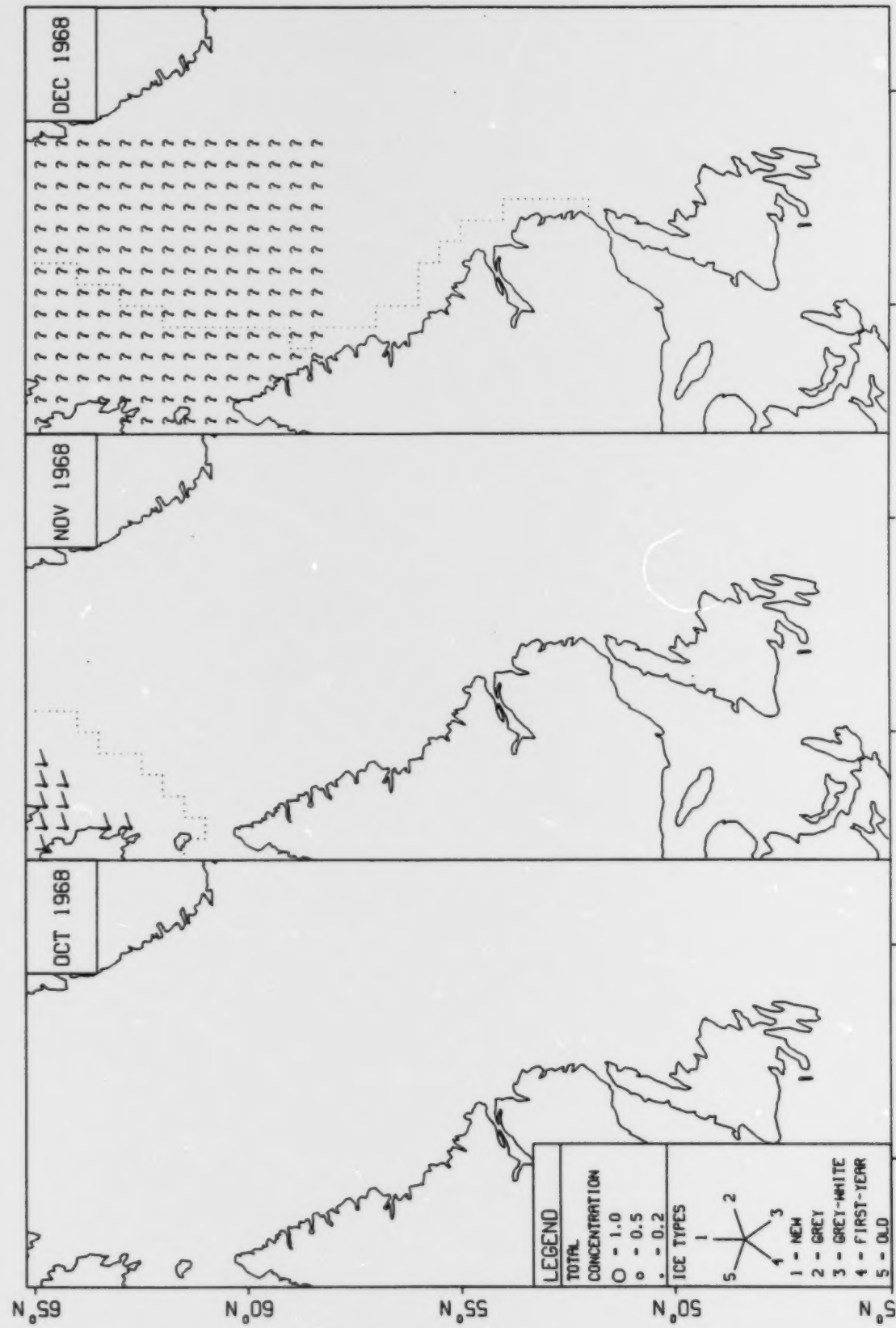
OCT 1968
NOV 1968
DEC 1968
LEGEND
TOTAL CONCENTRATION
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ICE TYPES
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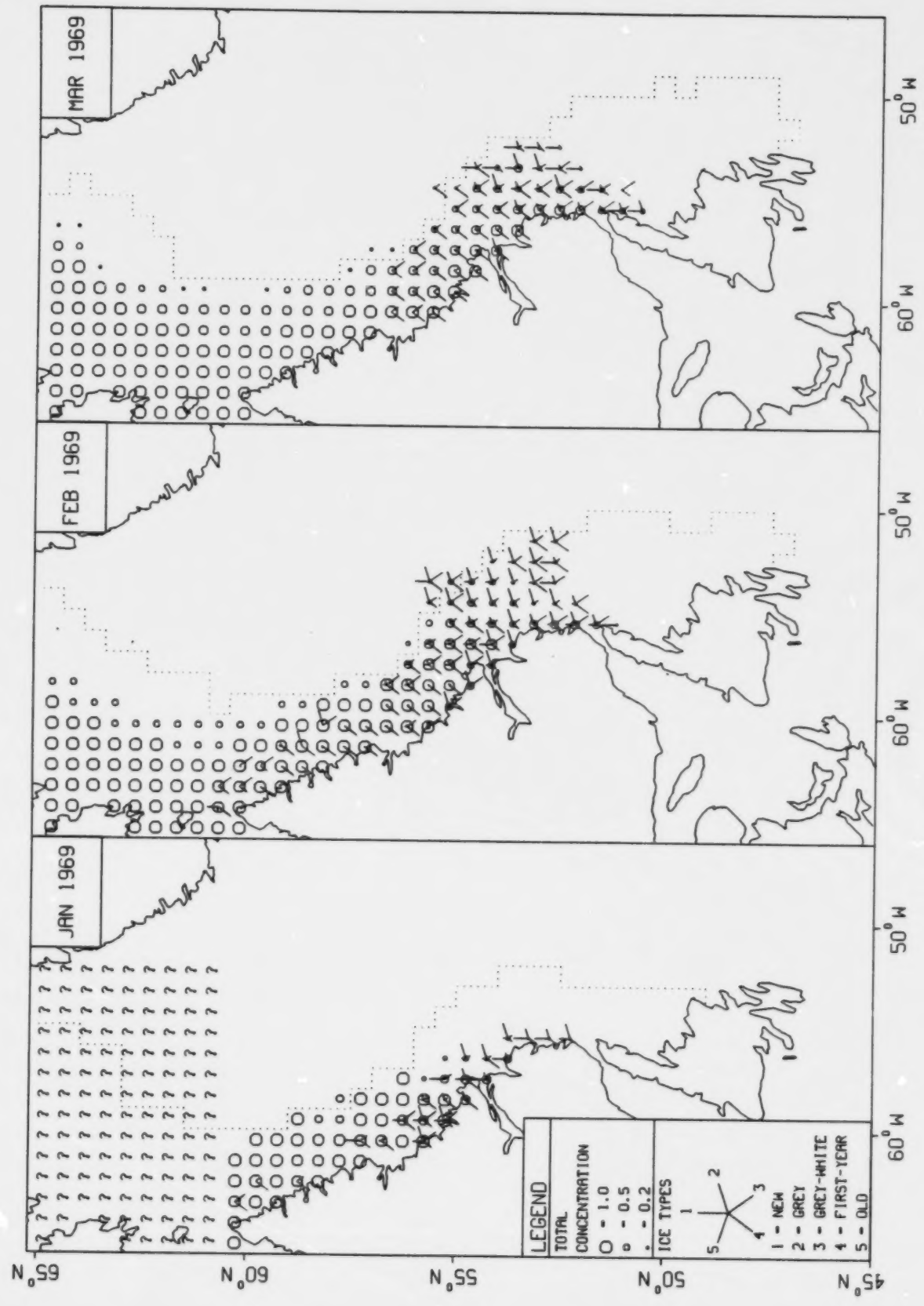
JAN 1969
FEB 1969
MAR 1969
LEGEND
TOTAL CONCENTRATION
○ - 1.0
o - 0.5
· - 0.2
ICE TYPES
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2 - GREY
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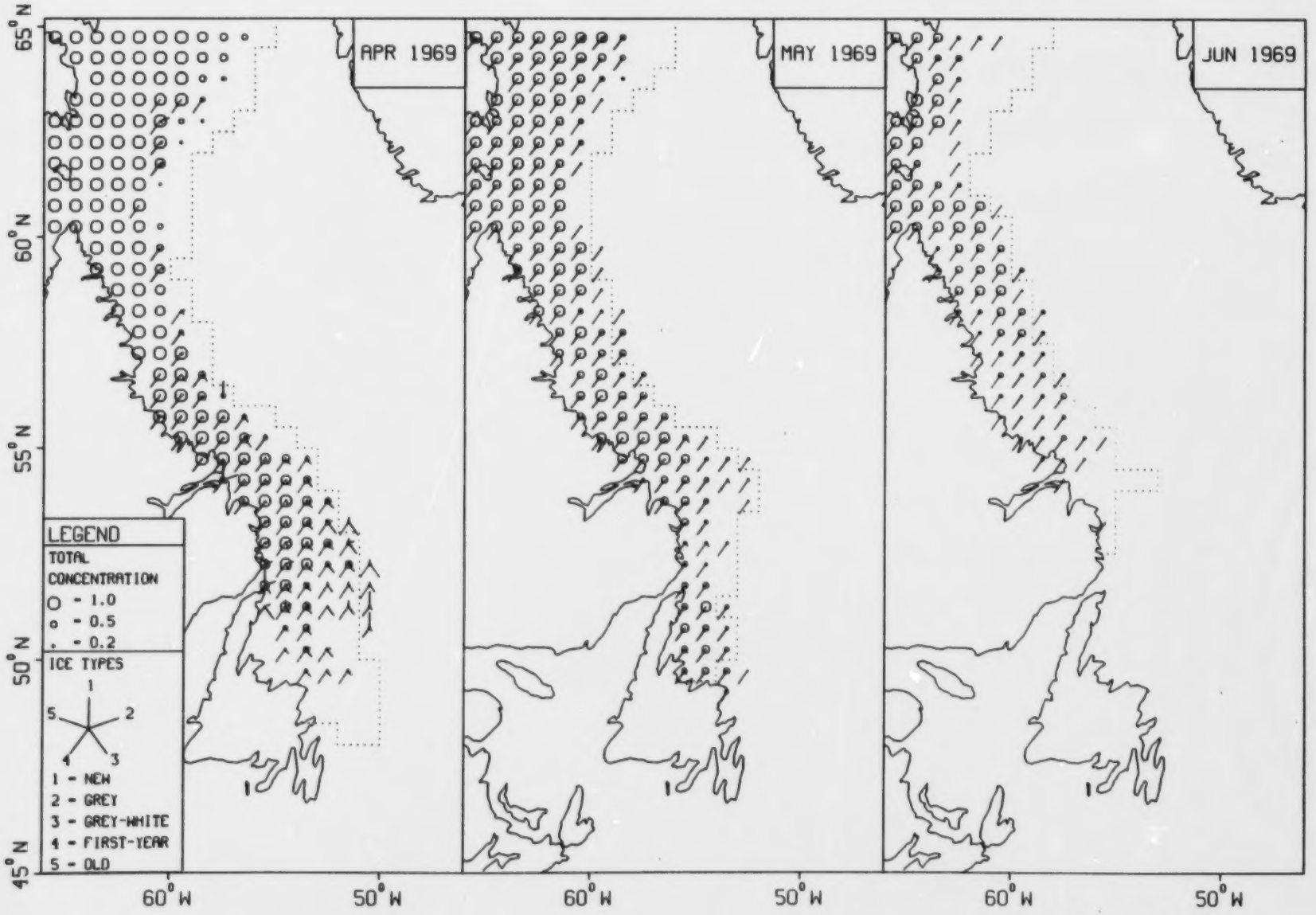
APR 1969
MAY 1969
JUN 1969
65°N
60°N
55°N
50°N
45°N
60°W
50°W
LEGEND
TOTAL CONCENTRATION
○ - 1.0
∘ - 0.5
. - 0.2
ICE TYPES
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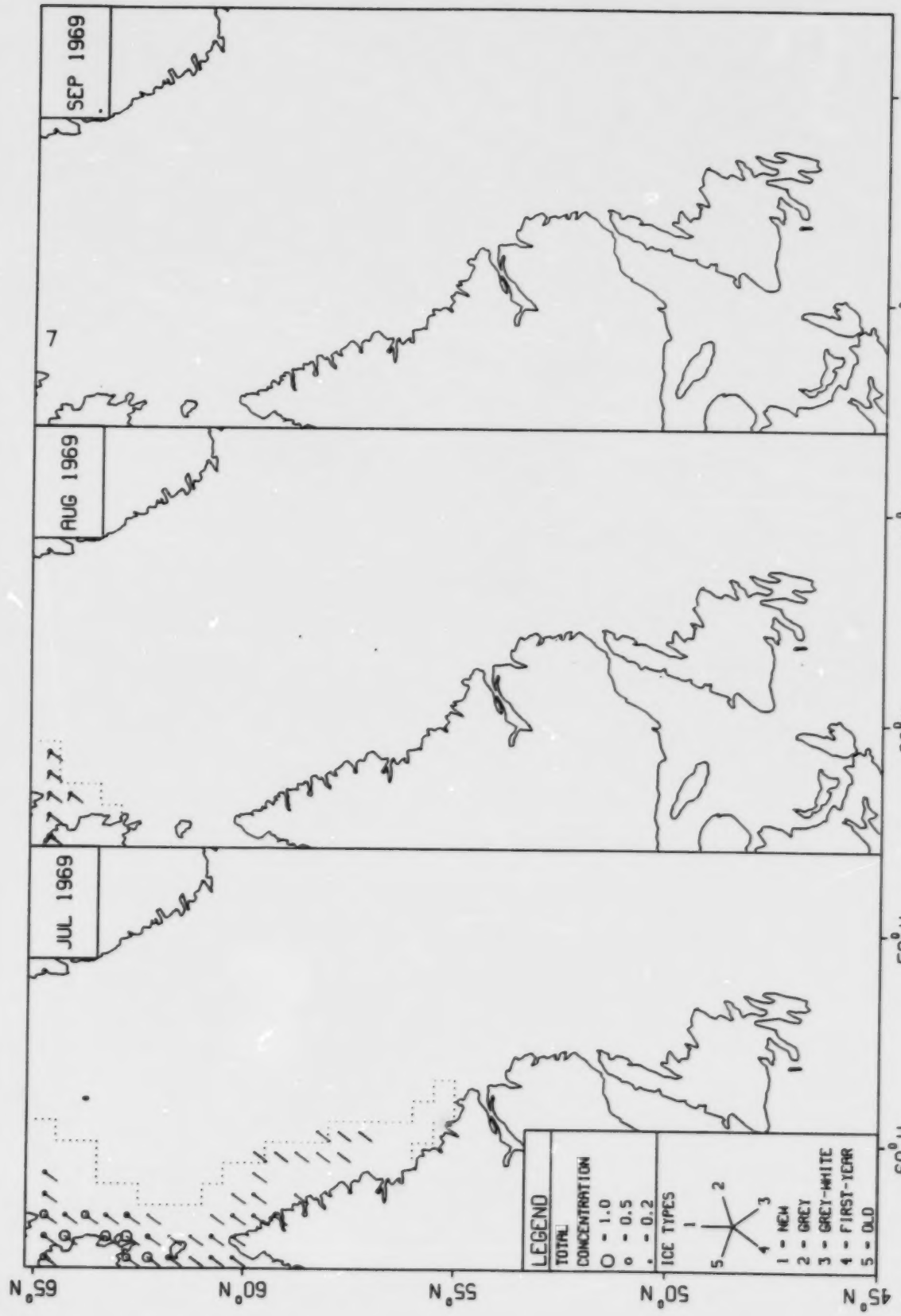
2
3
4
5
1 - NEW
2 - GREY
3 - GREY-WHITE
4 - FIRST-YEAR
5 - OLD


JUL 1969
AUG 1969
SEP 1969
7
LEGEND
TOTAL
CONCENTRATION
O - 1.0
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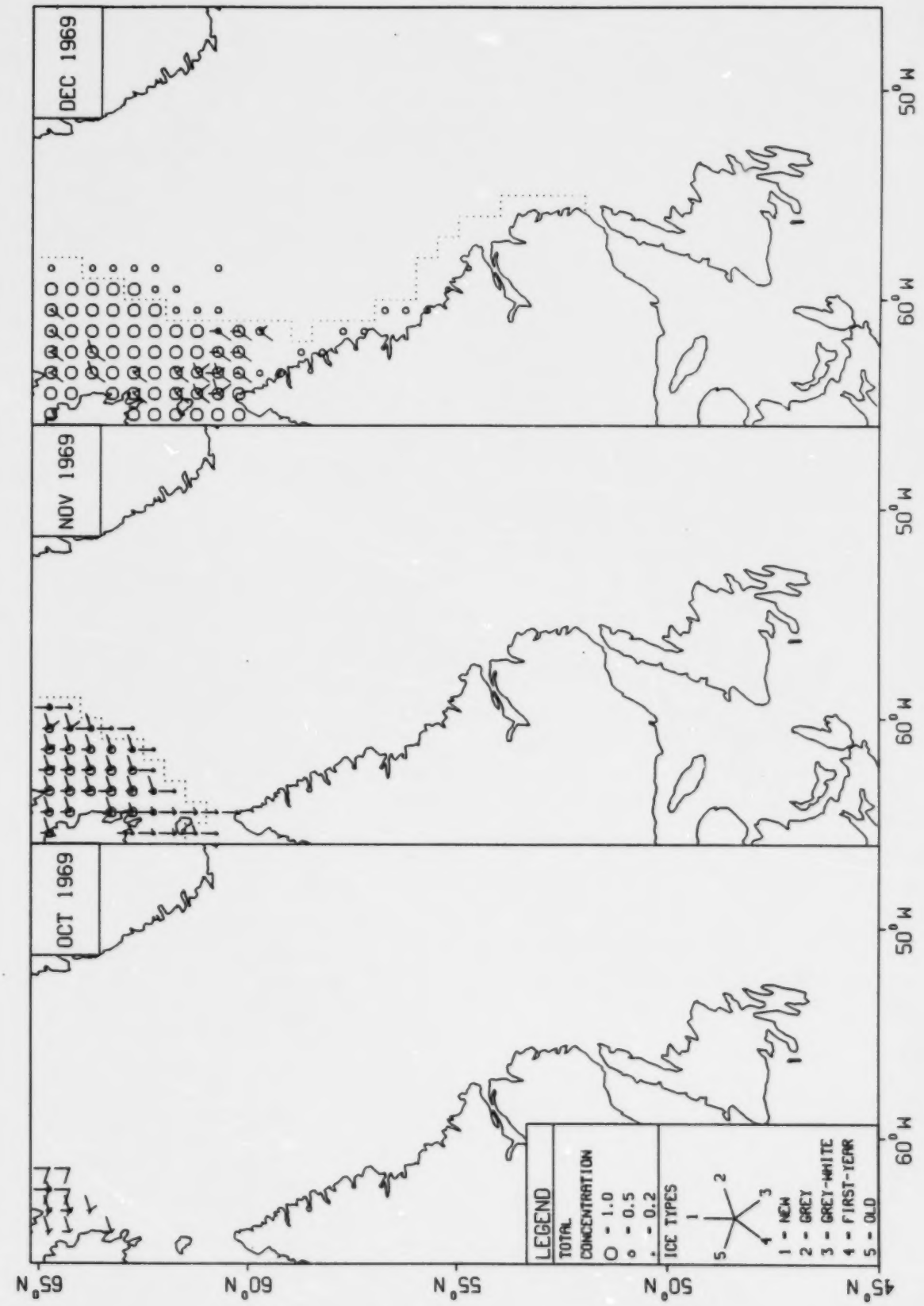
. - 0.2
ICE TYPES
1
2
3
4
5
1 - NEW
2 - GREY
3 - GREY-WHITE
4 - FIRST-YEAR
5 - OLD
65°N
60°N
55°N
50°N
45°N
60°W
50°W


OCT 1969
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DEC 1969
LEGEND
TOTAL CONCENTRATION
O - 1.0
o - 0.5
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ICE TYPES
1 - NEW
2 - GREY
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65°N
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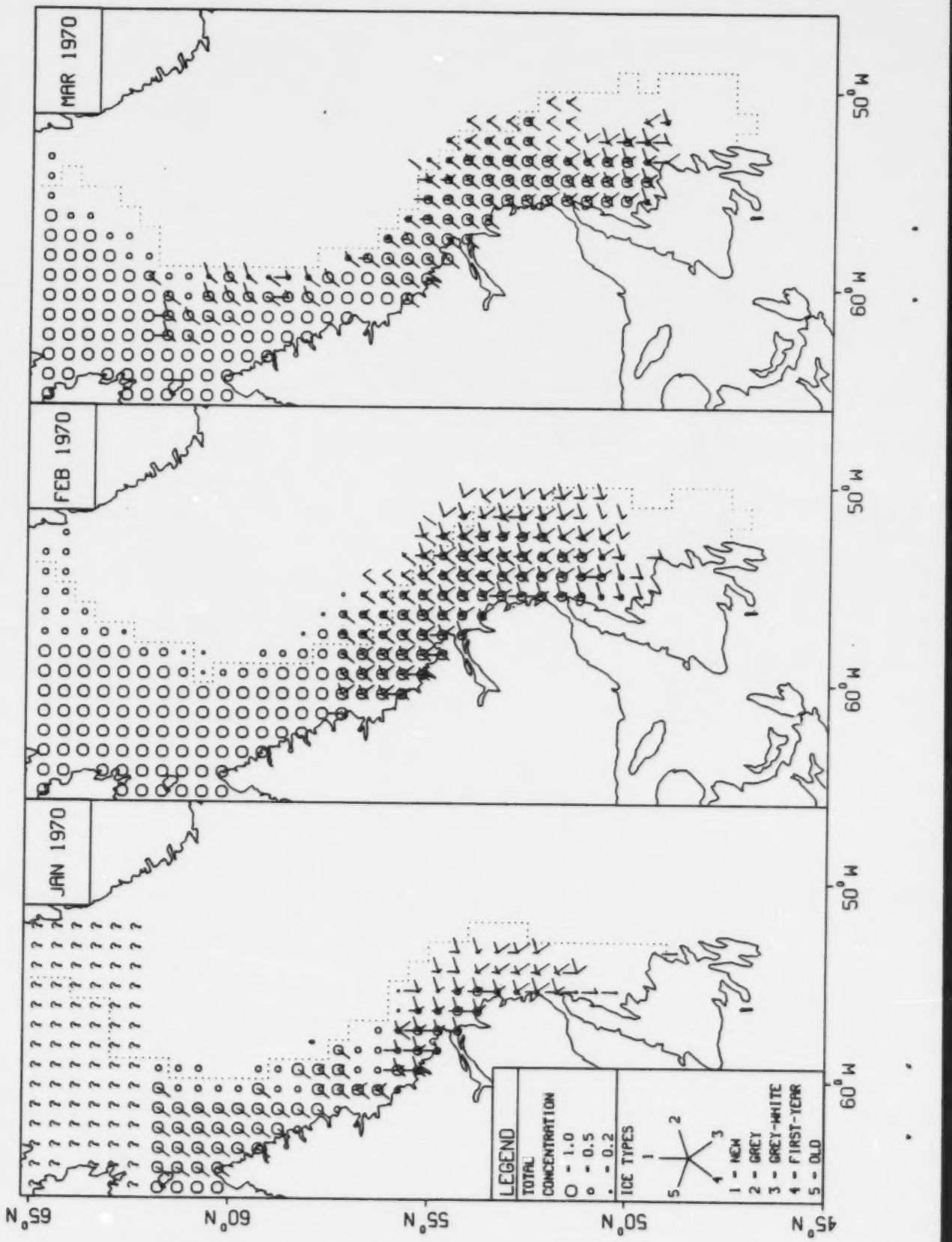
MAR 1970
FEB 1970
JAN 1970
LEGEND
TOTAL CONCENTRATION
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. - 0.2
ICE TYPES
1 - NEW
2 - GREY
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4 - FIRST-YEAR
5 - OLD
65°N
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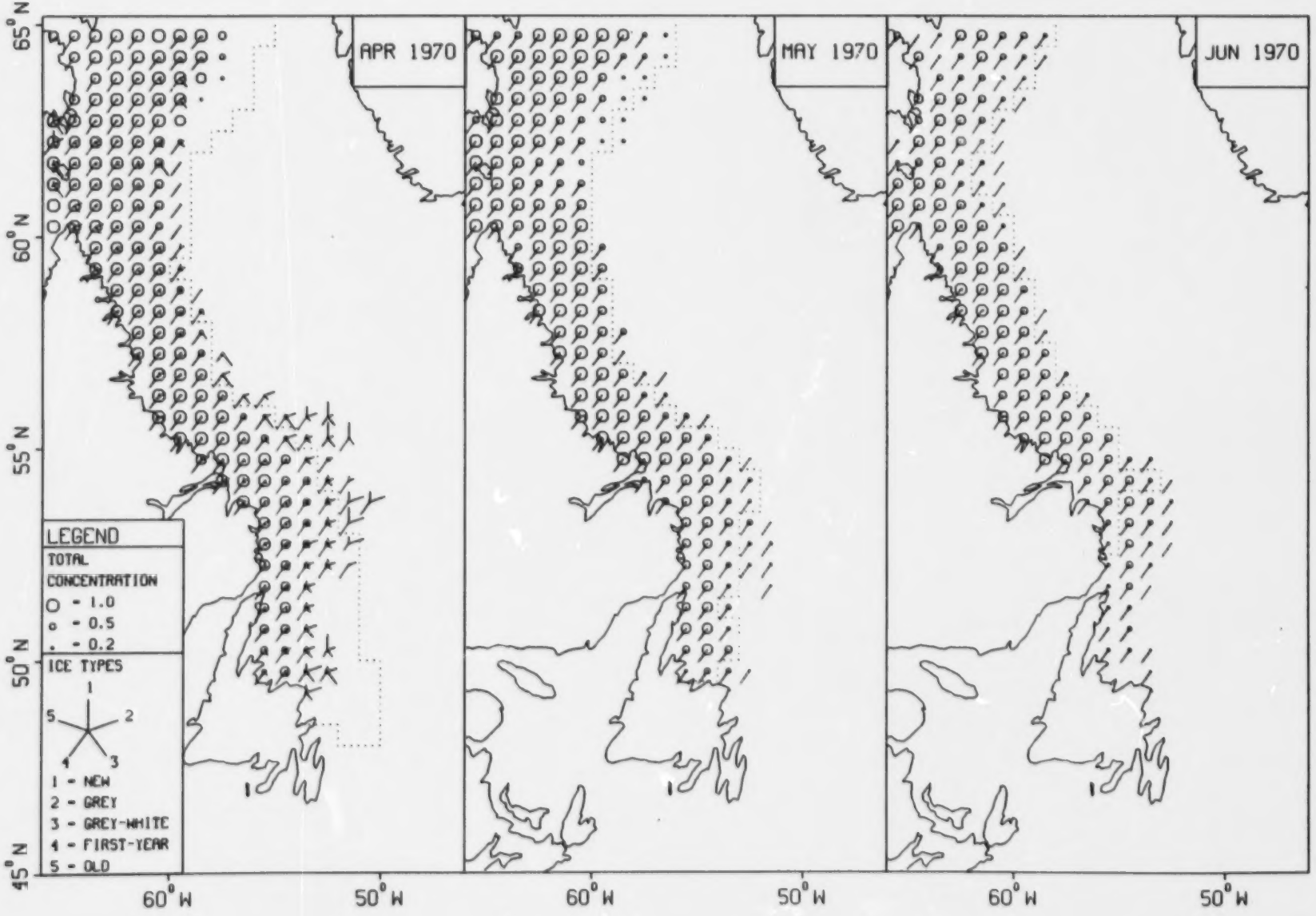
APR 1970
MAY 1970
JUN 1970
65°N
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50°N
45°N
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LEGEND
TOTAL
CONCENTRATION
○ - 1.0
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ICE TYPES
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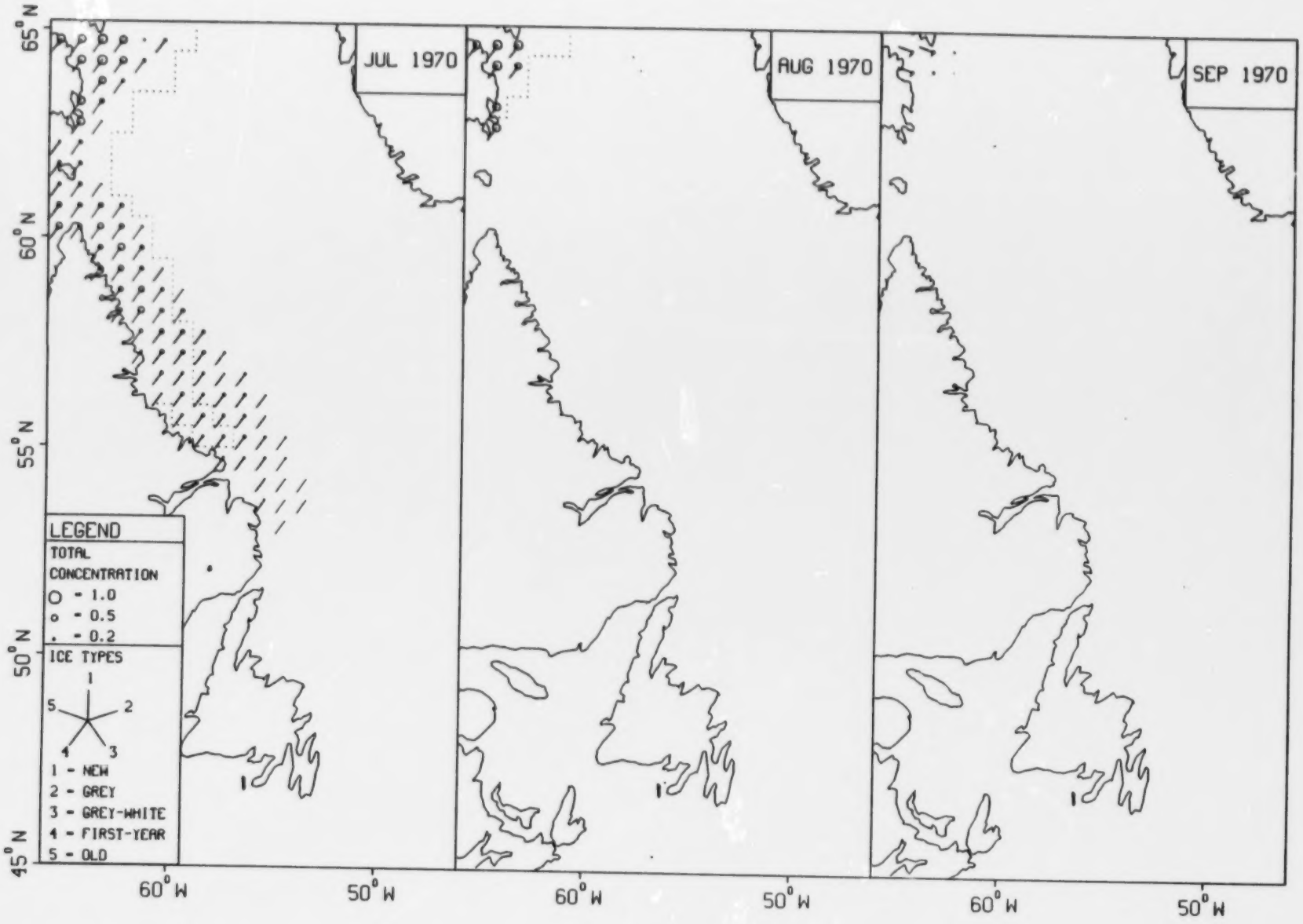
3 - GREY-WHITE
4 - FIRST-YEAR
5 - OLD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LEGEND
TOTAL CONCENTRATION
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ICE TYPES
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1 - NEW
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3 - GREY-WHITE
4 - FIRST-YEAR
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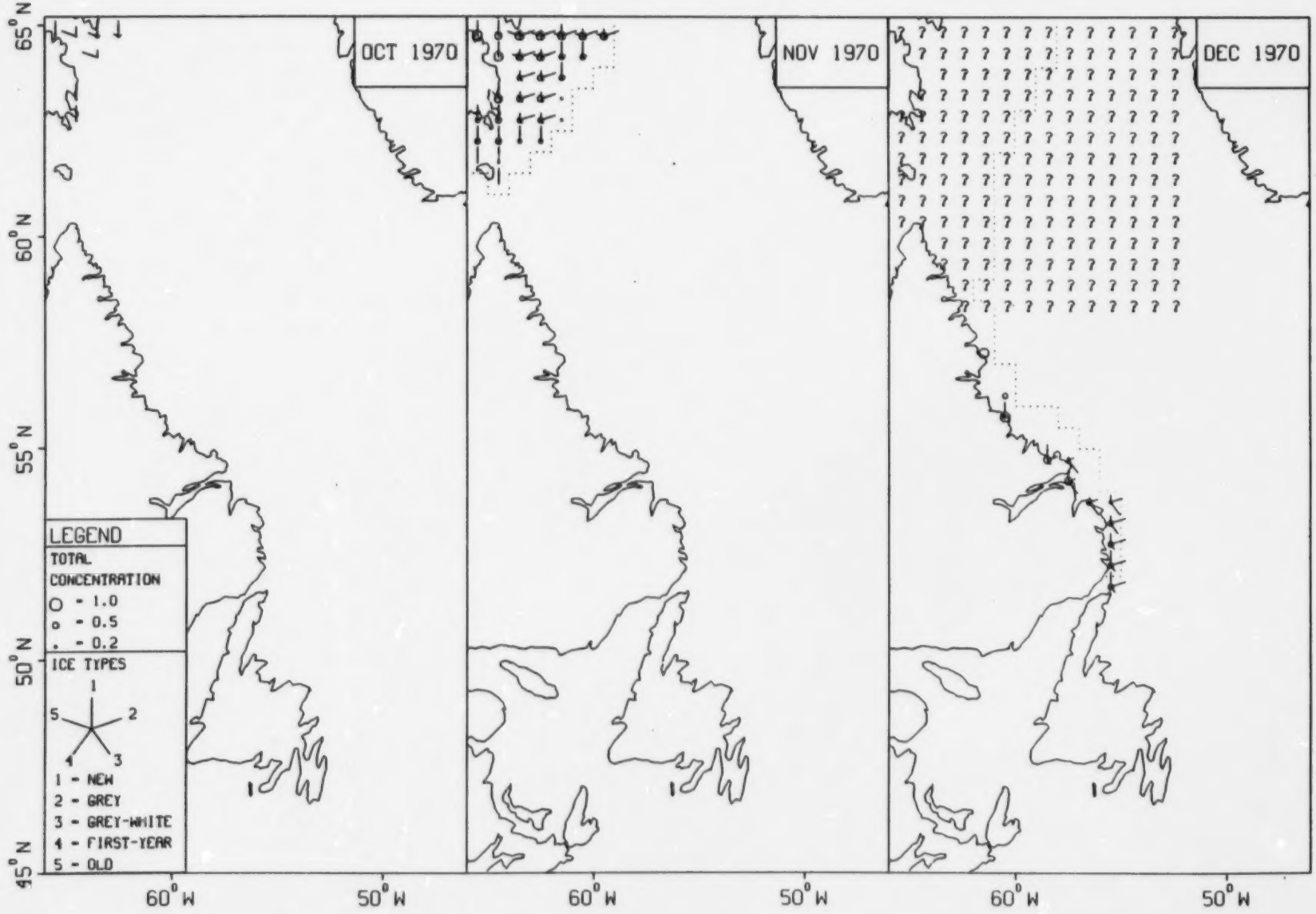
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LEGEND
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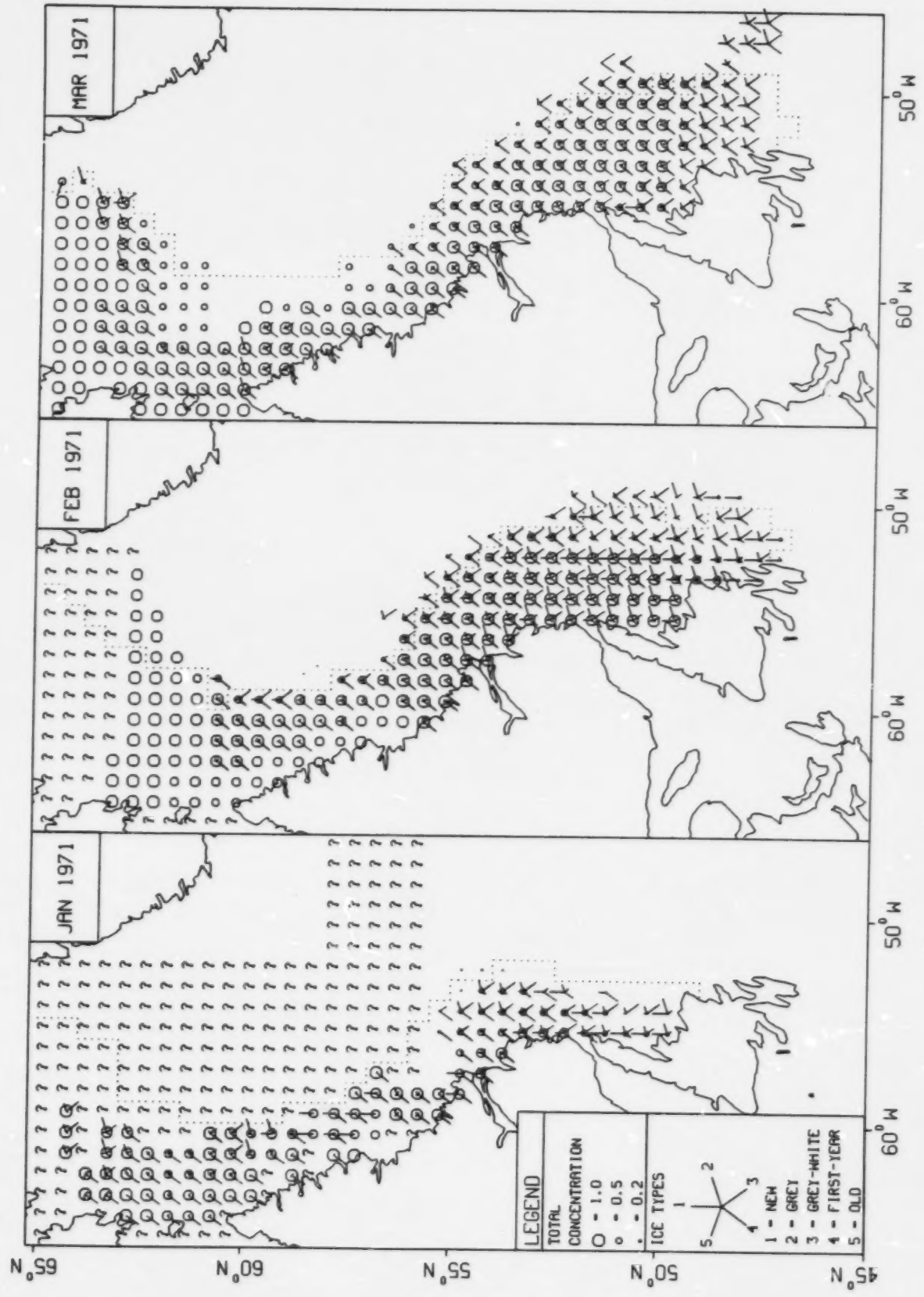
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ICE TYPES
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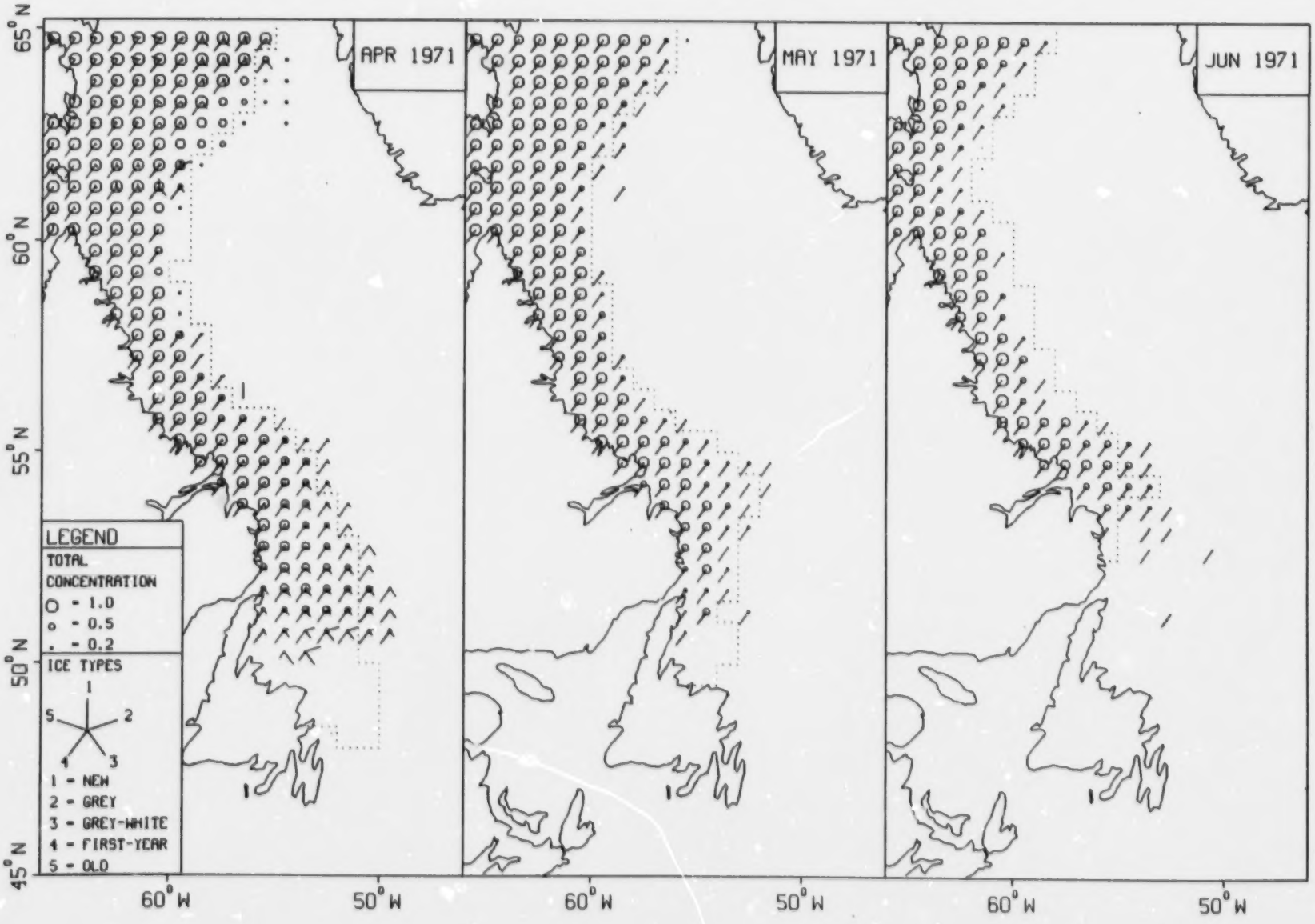
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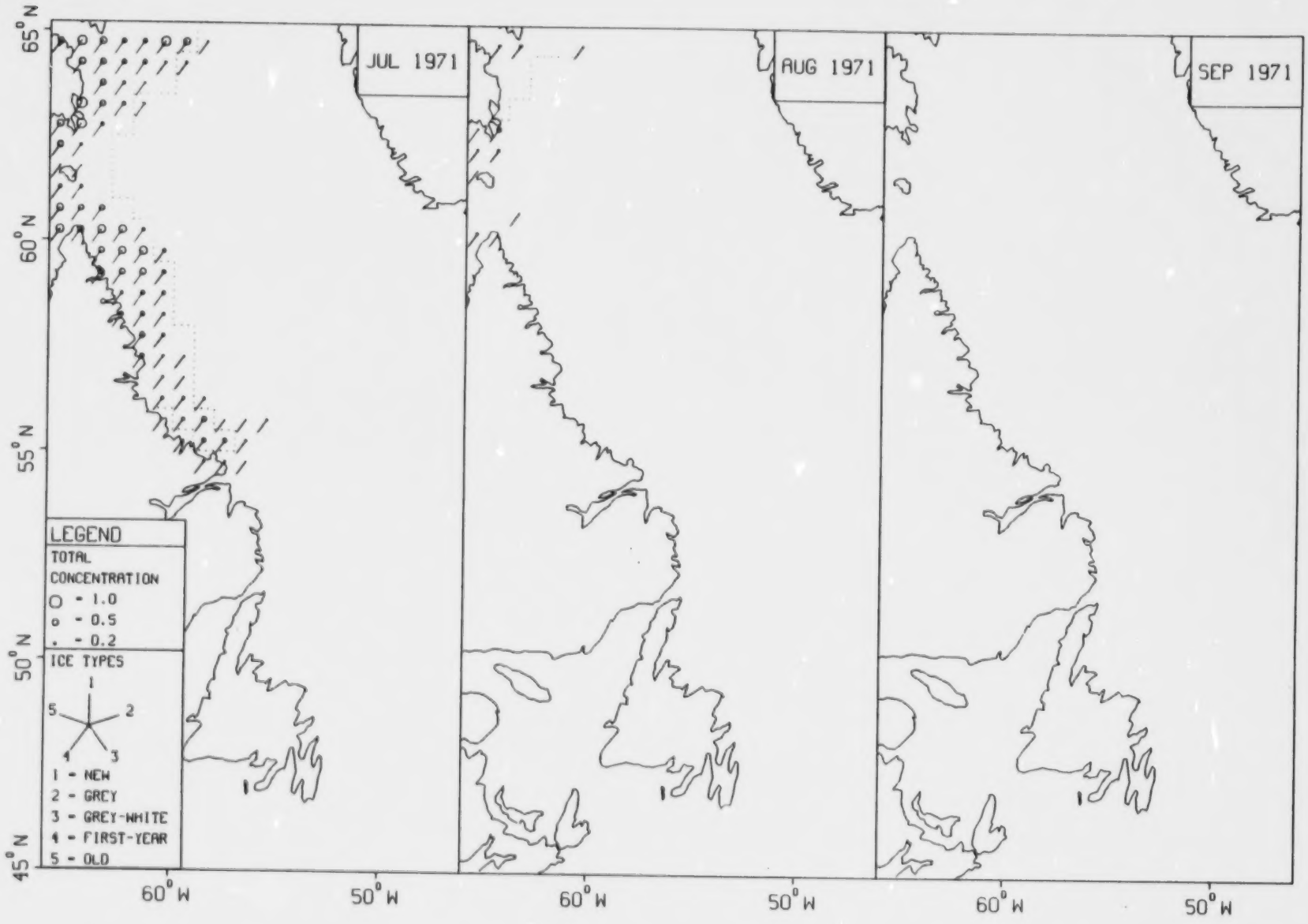
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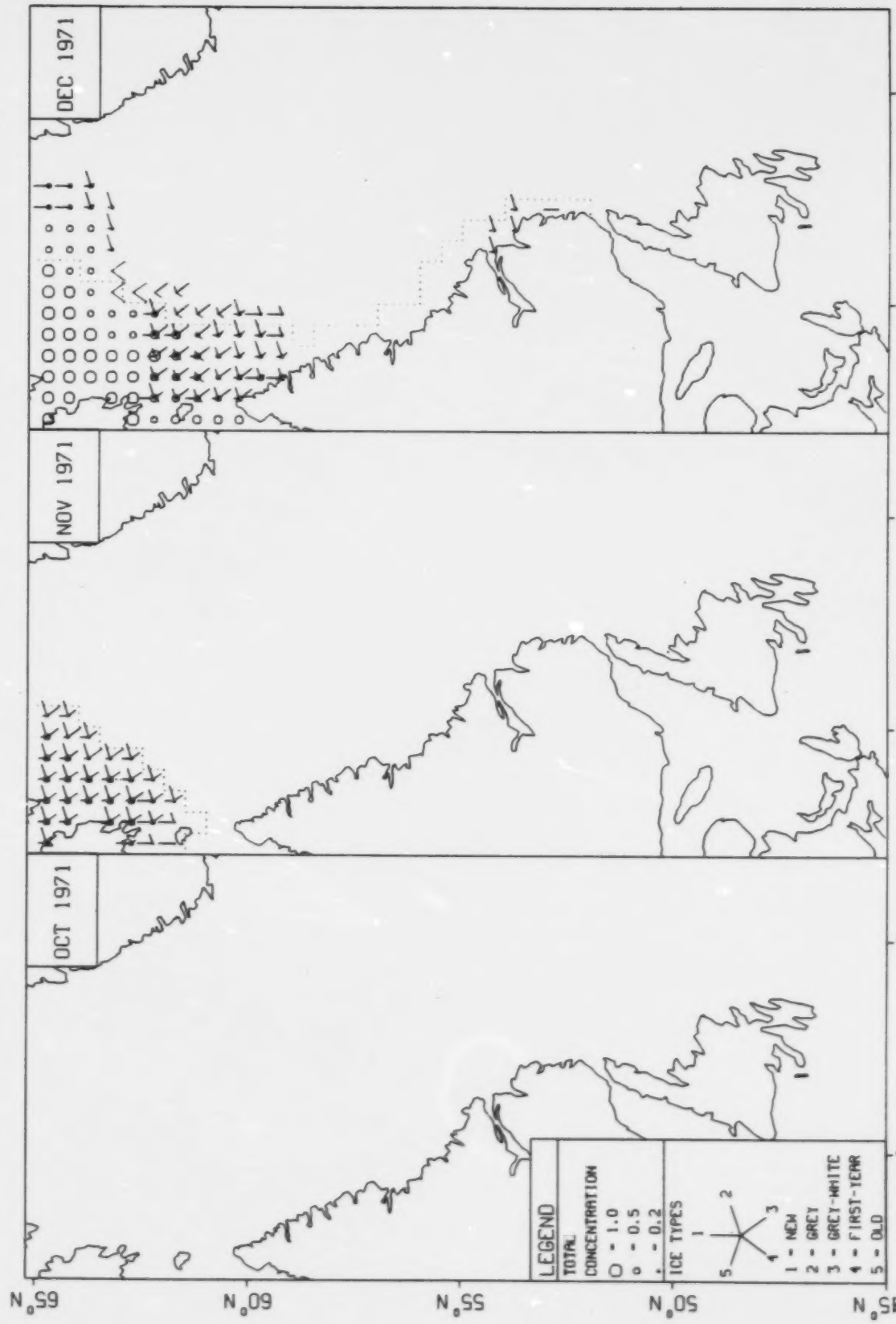
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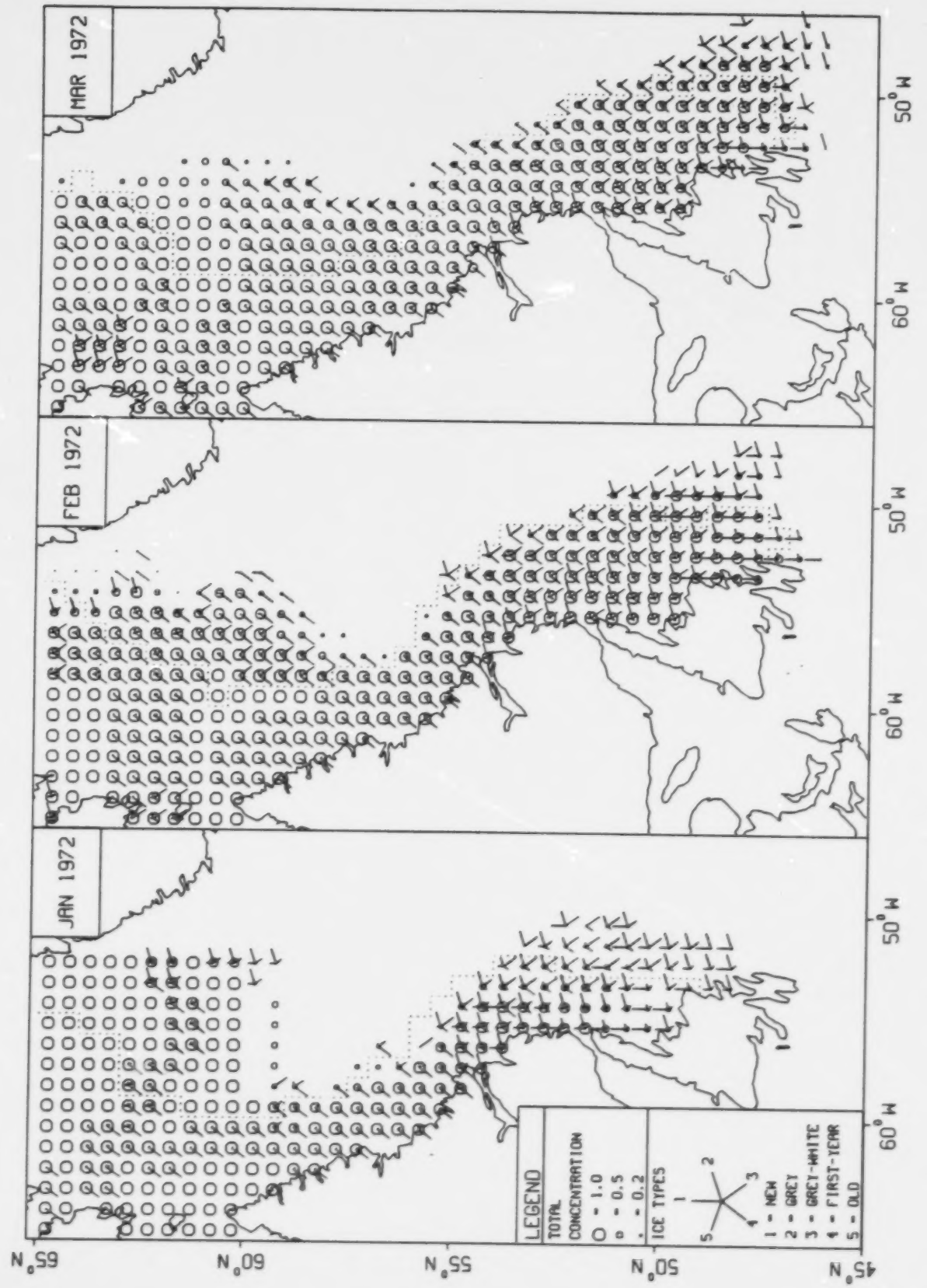
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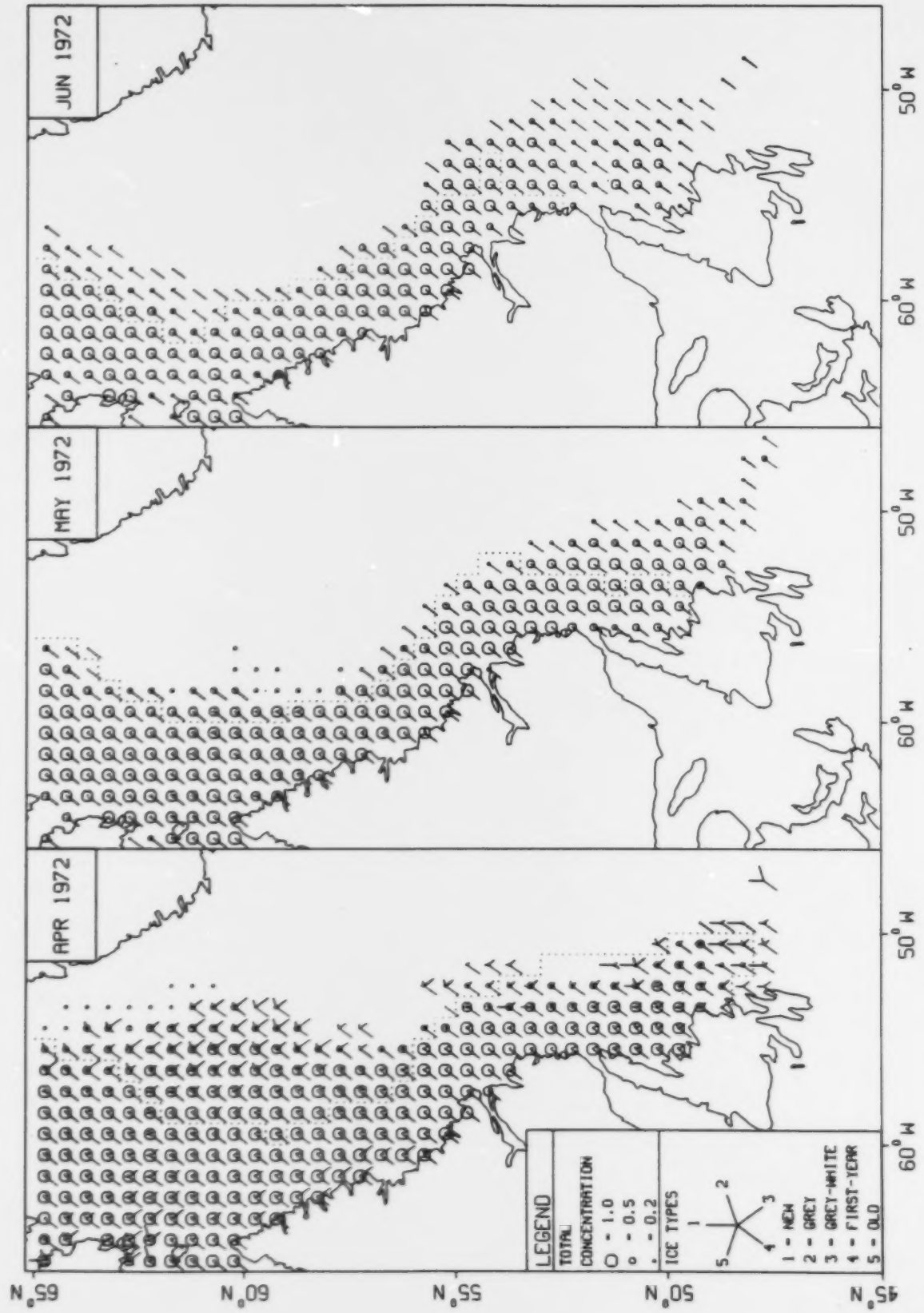
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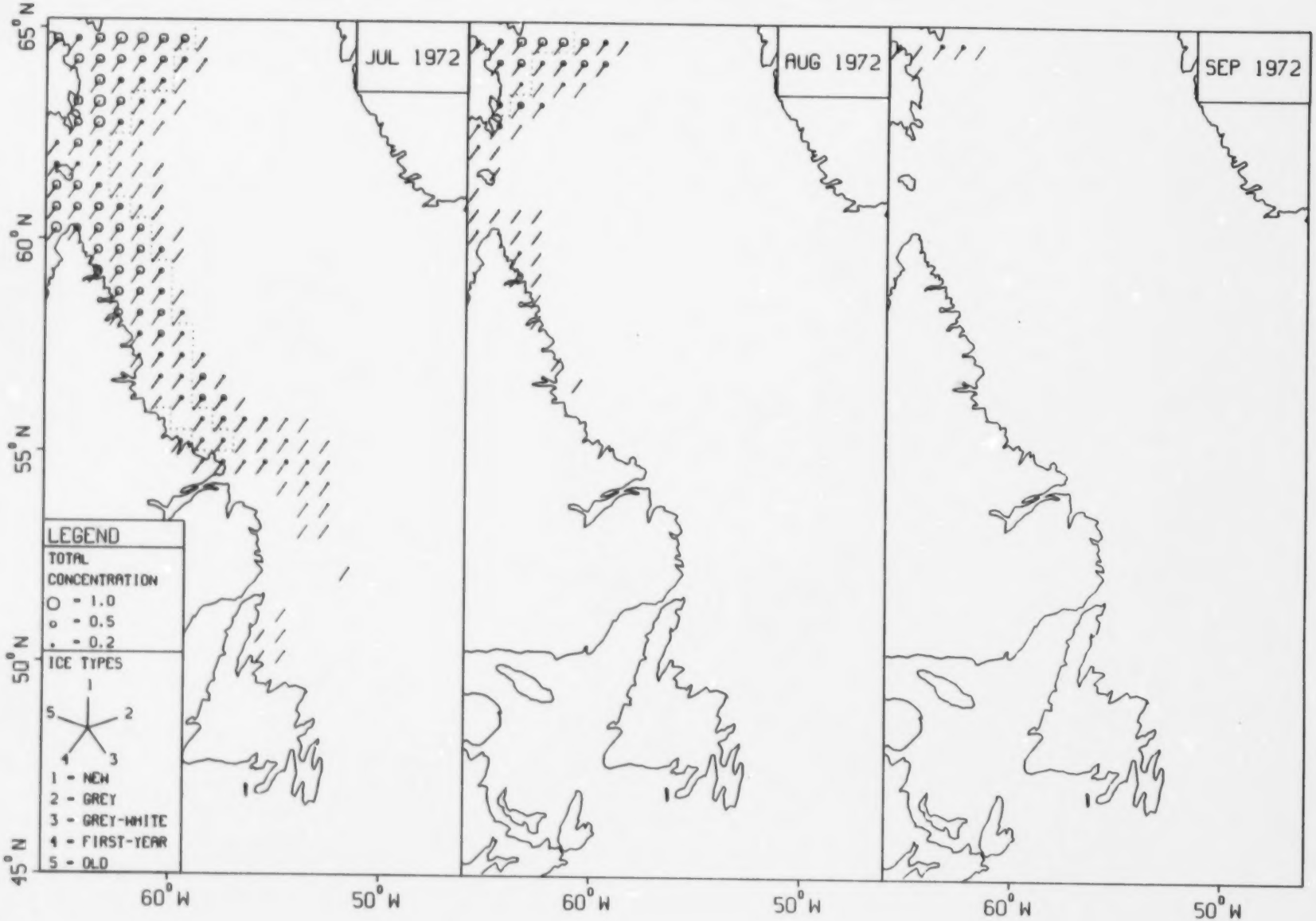
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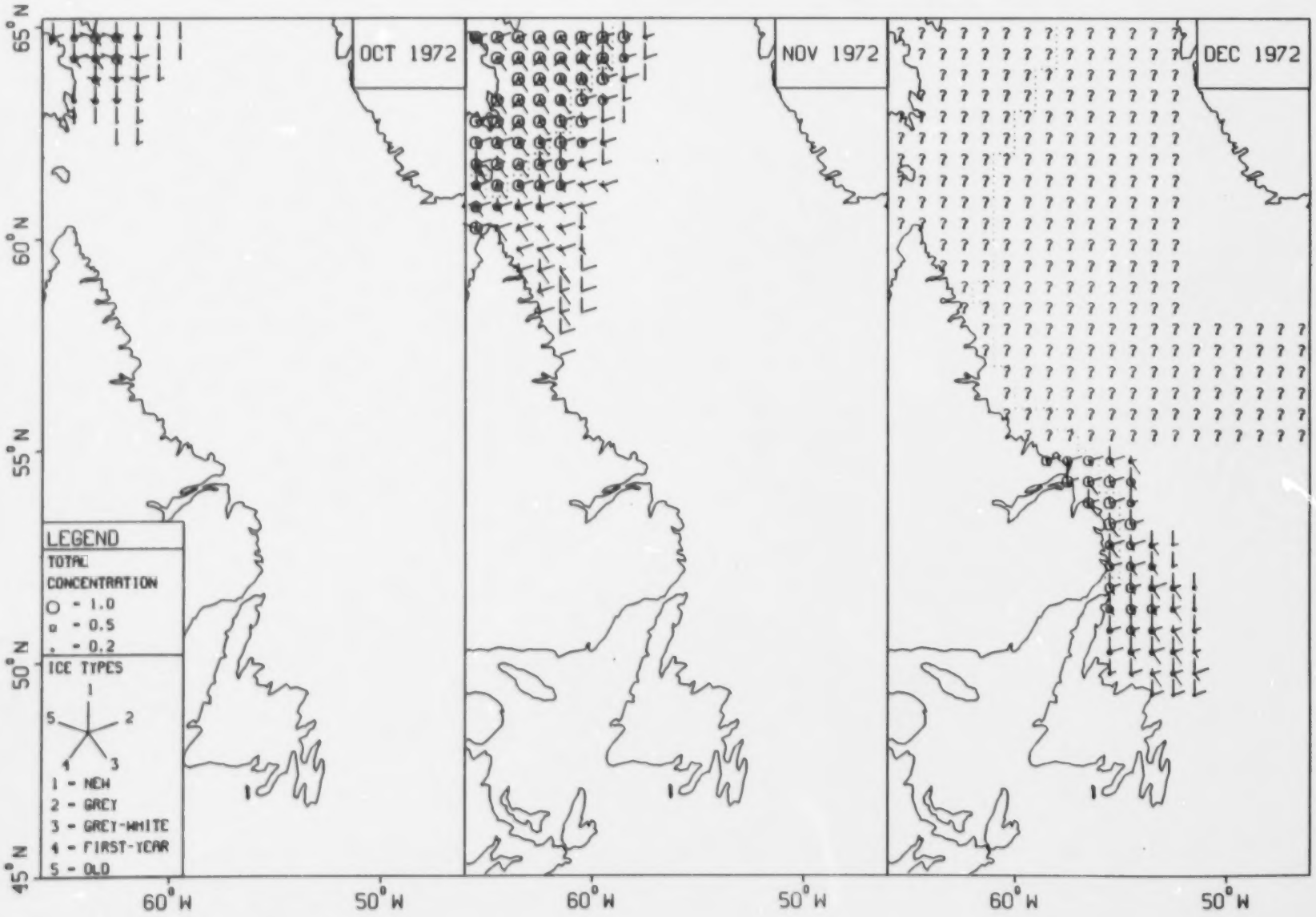
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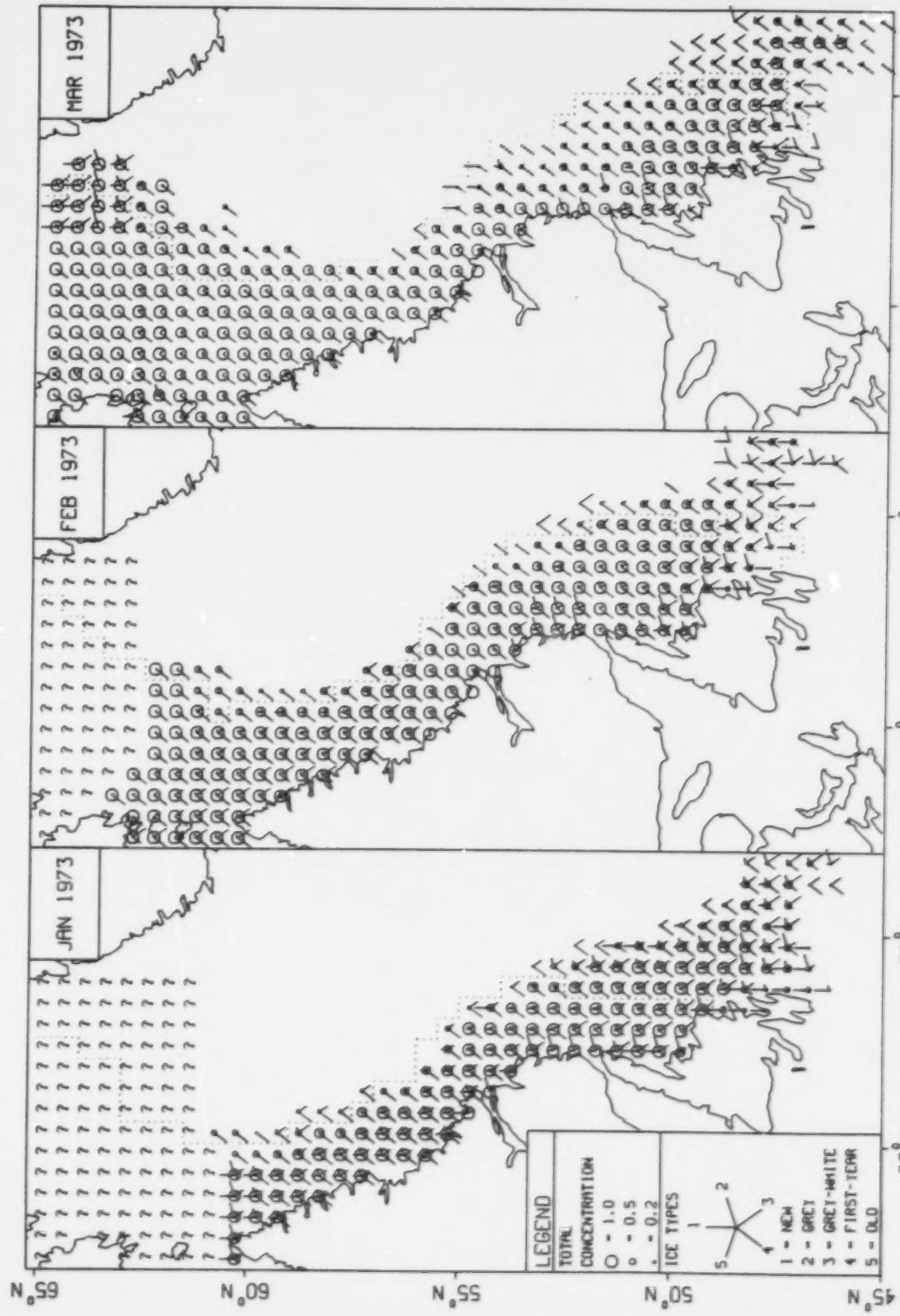
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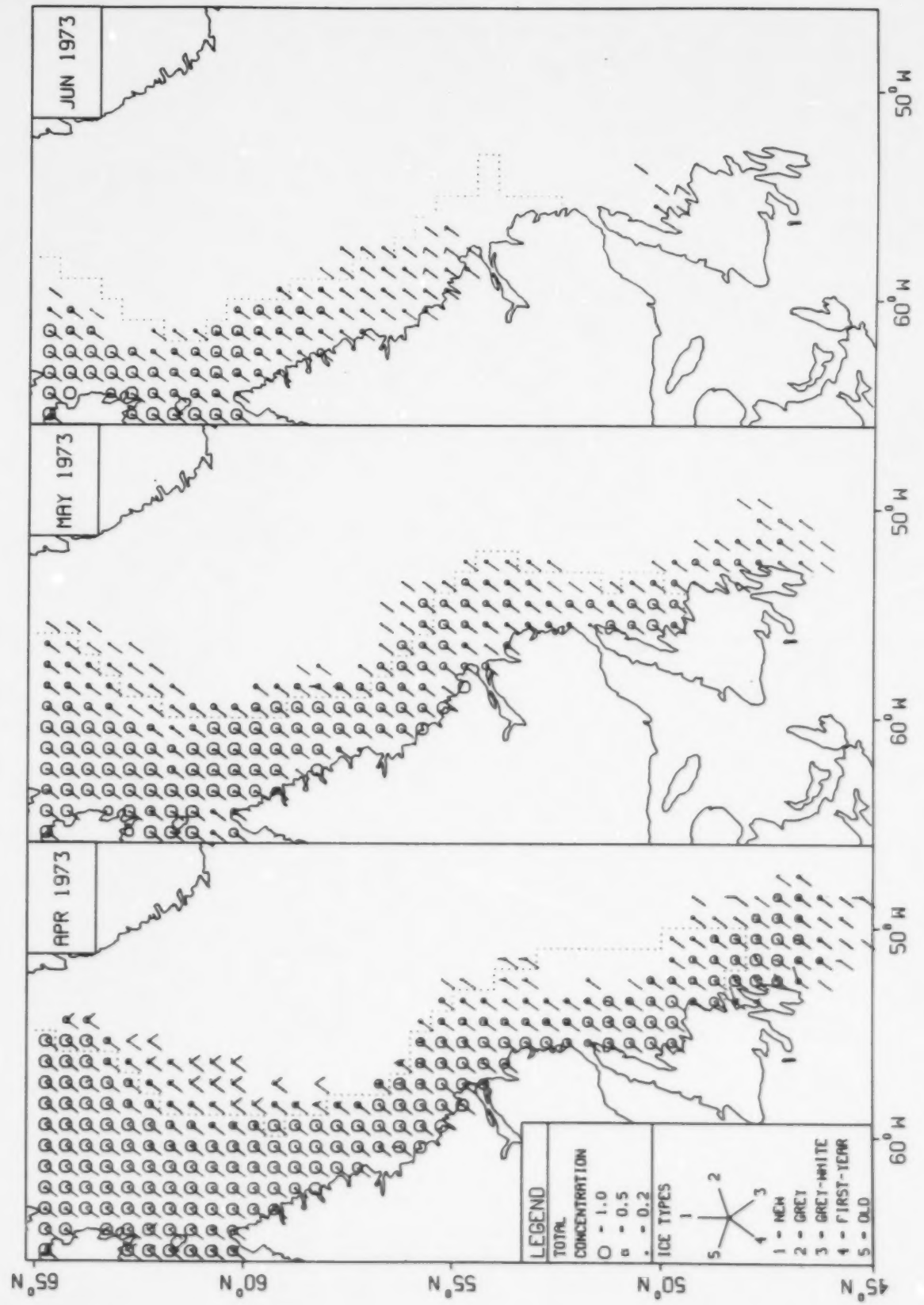
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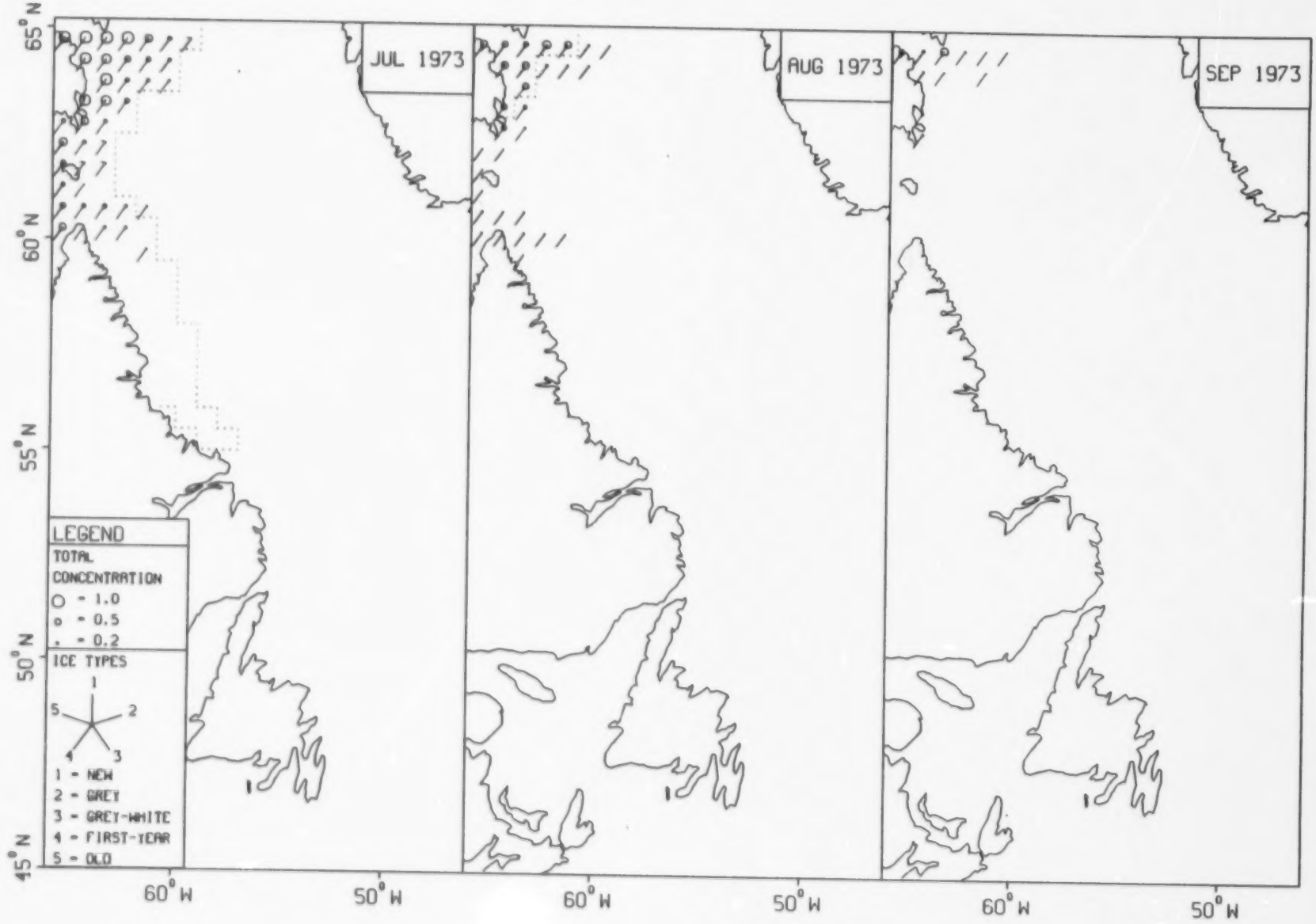
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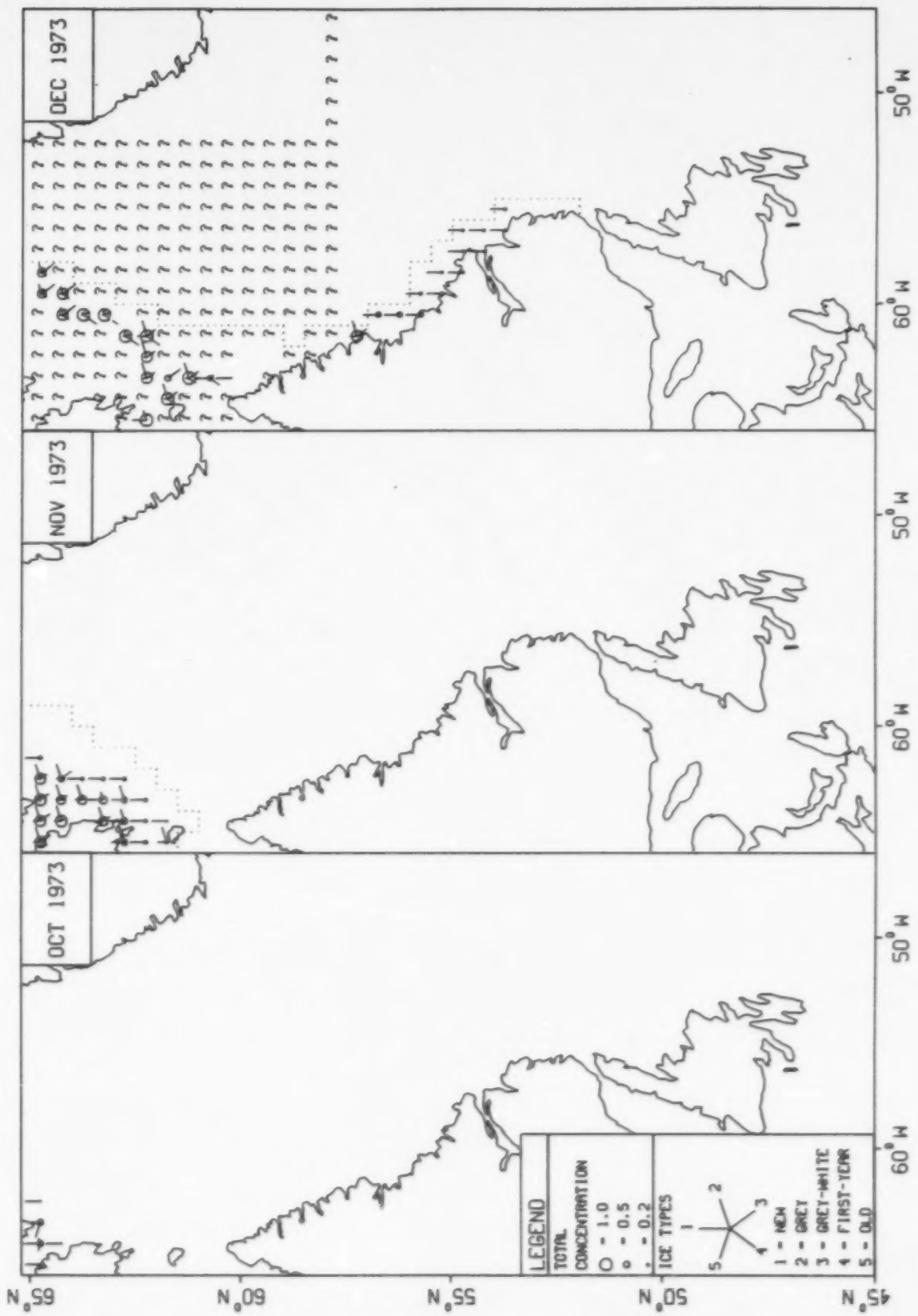
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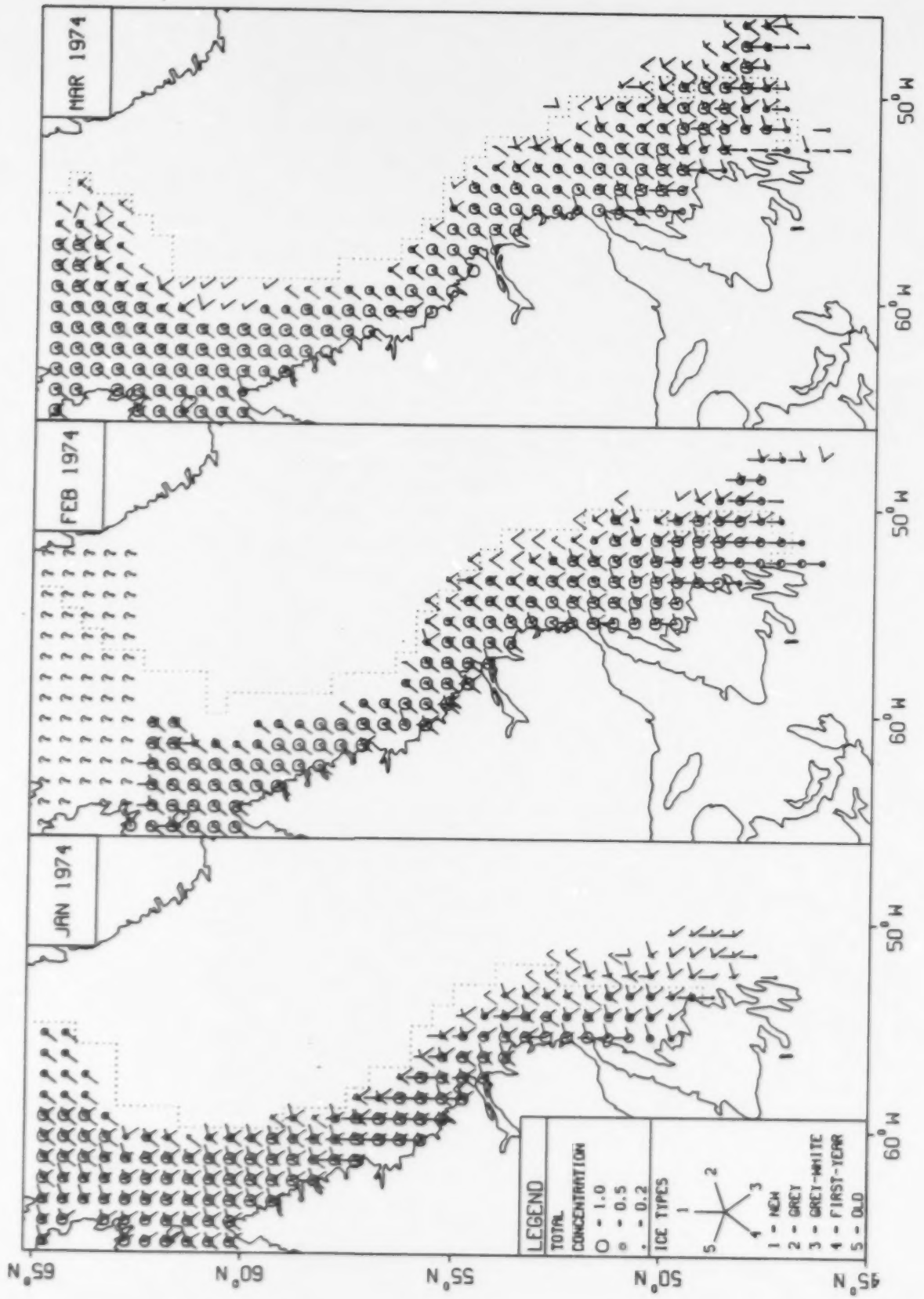
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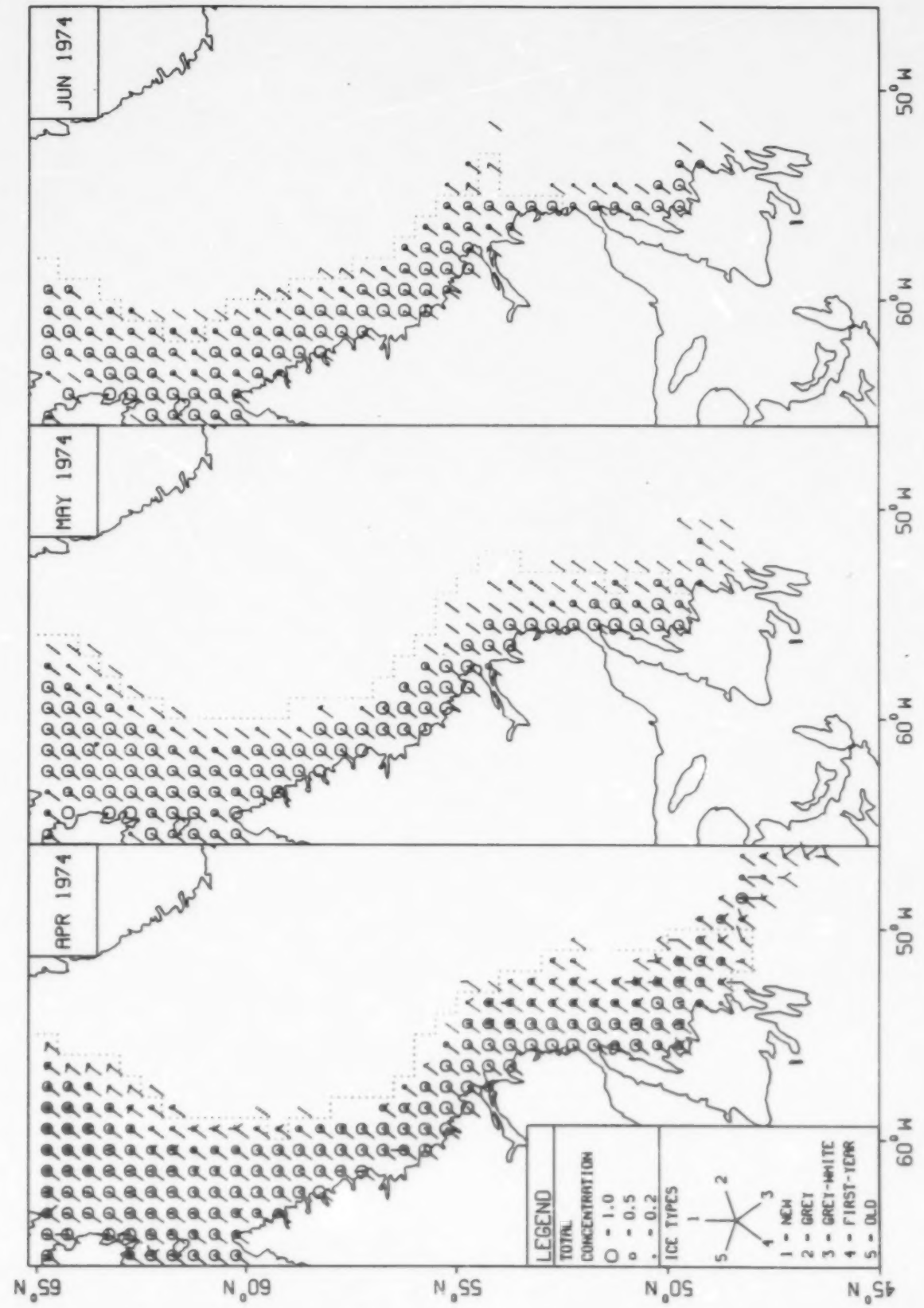
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ICE TYPES
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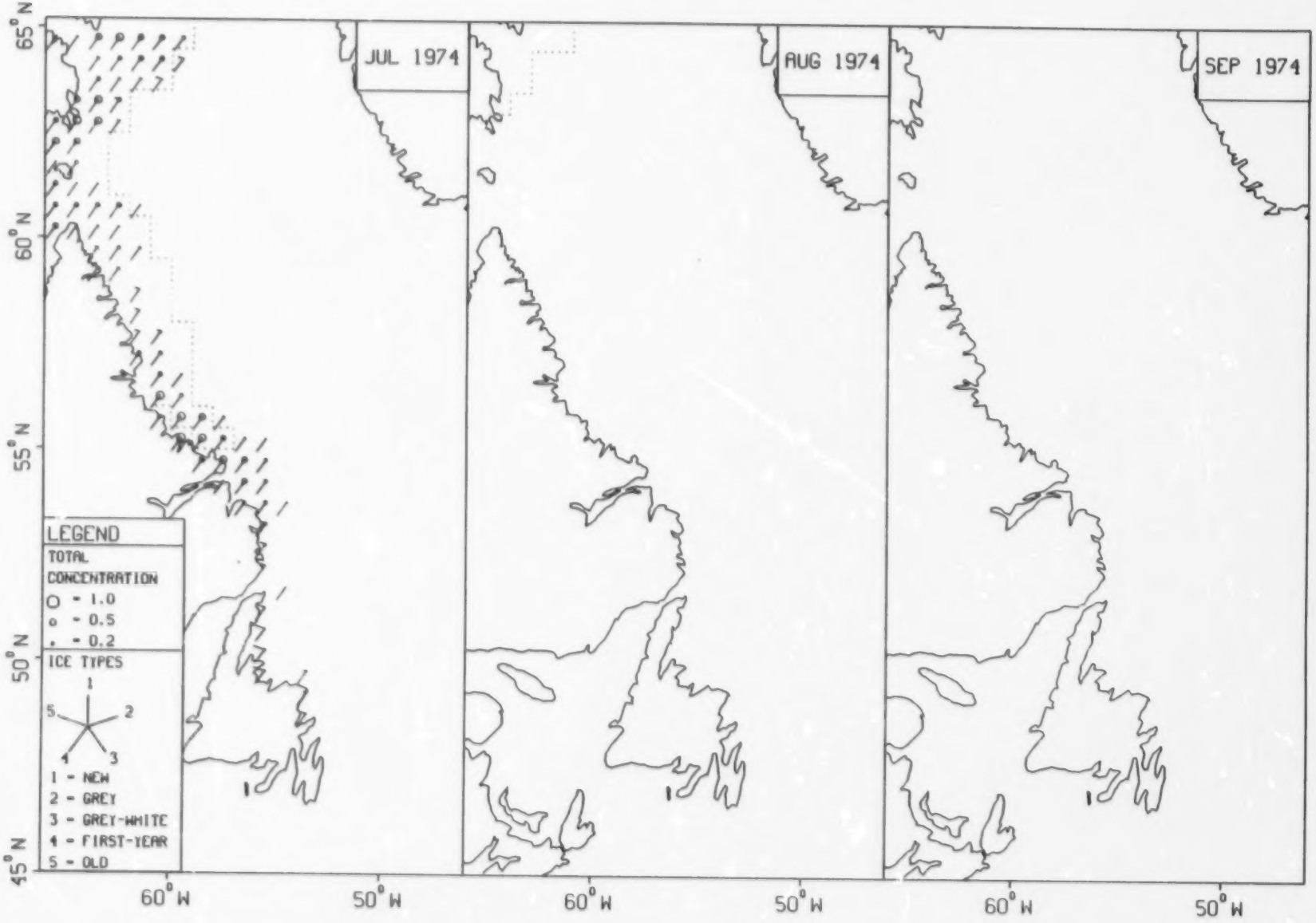
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TOTAL CONCENTRATION
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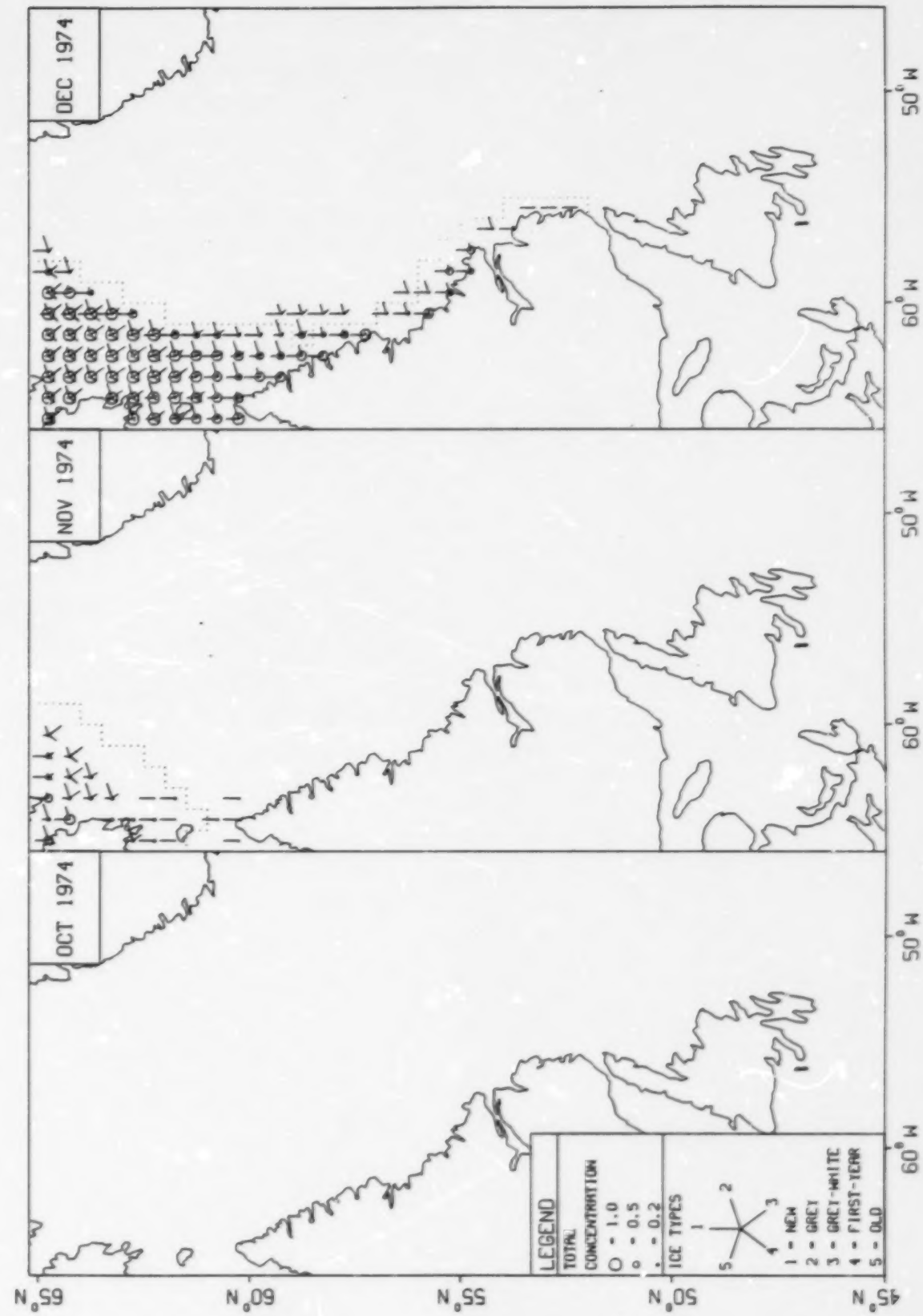
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TOTAL CONCENTRATION
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ICE TYPES
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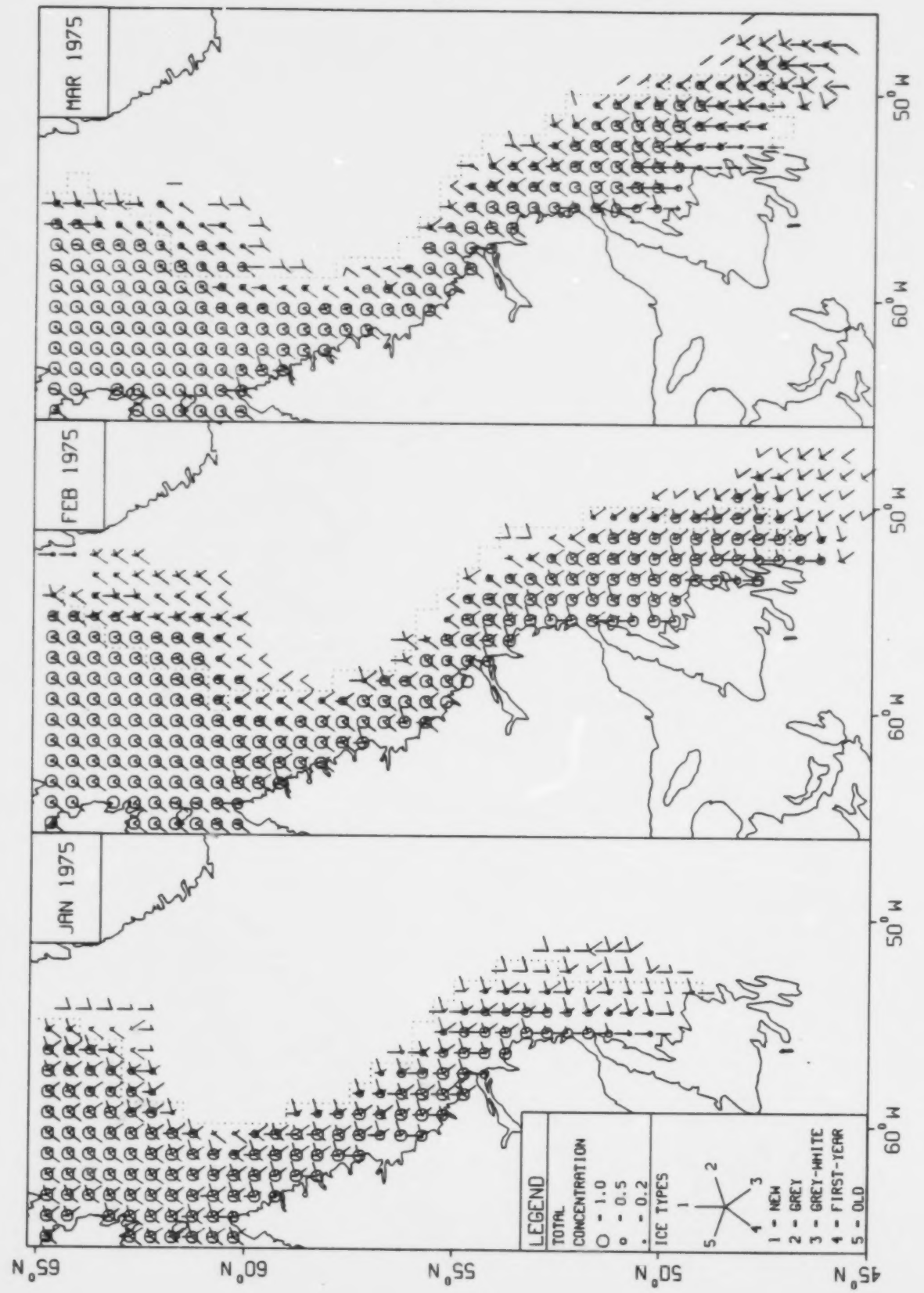
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ICE TYPES
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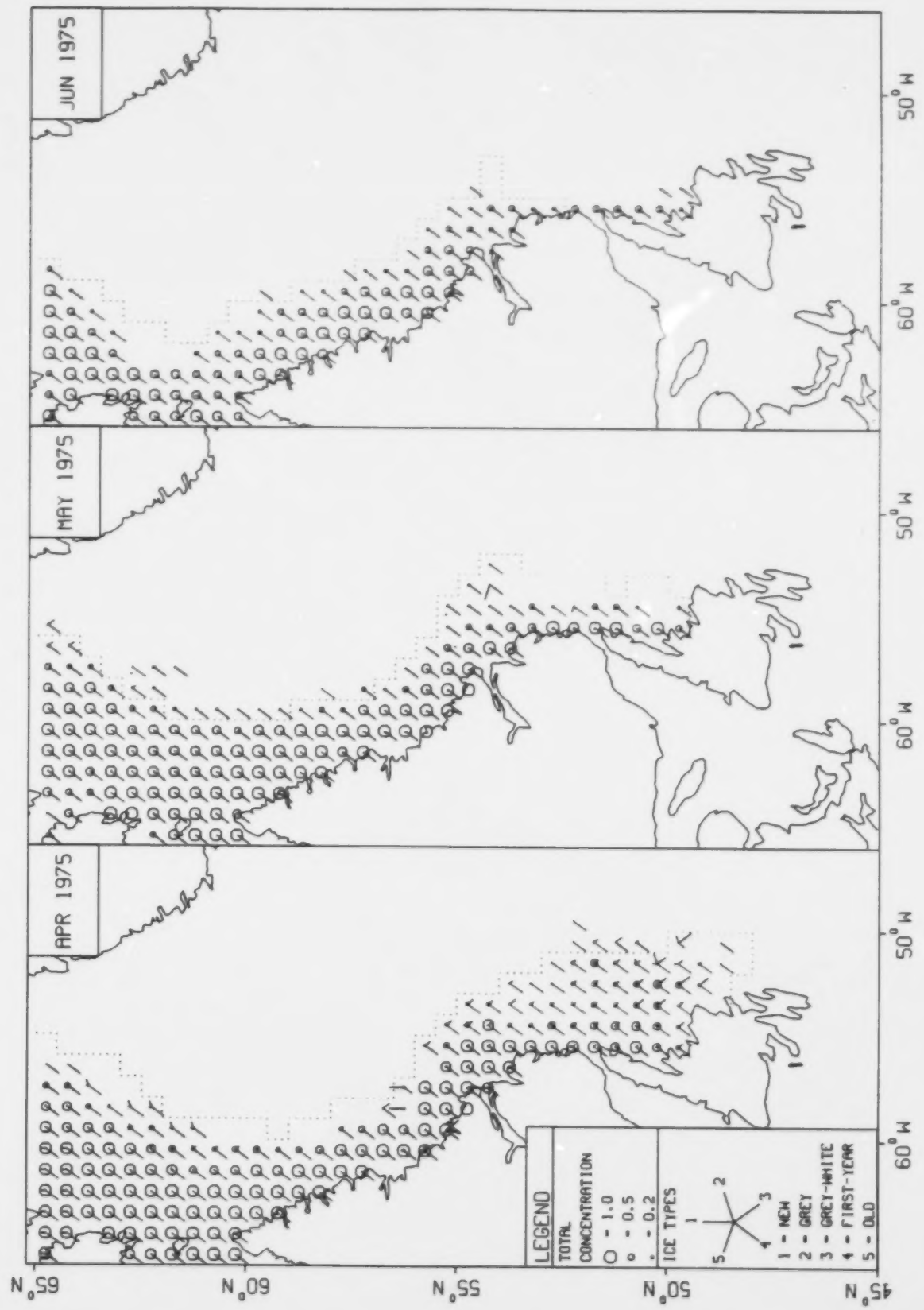
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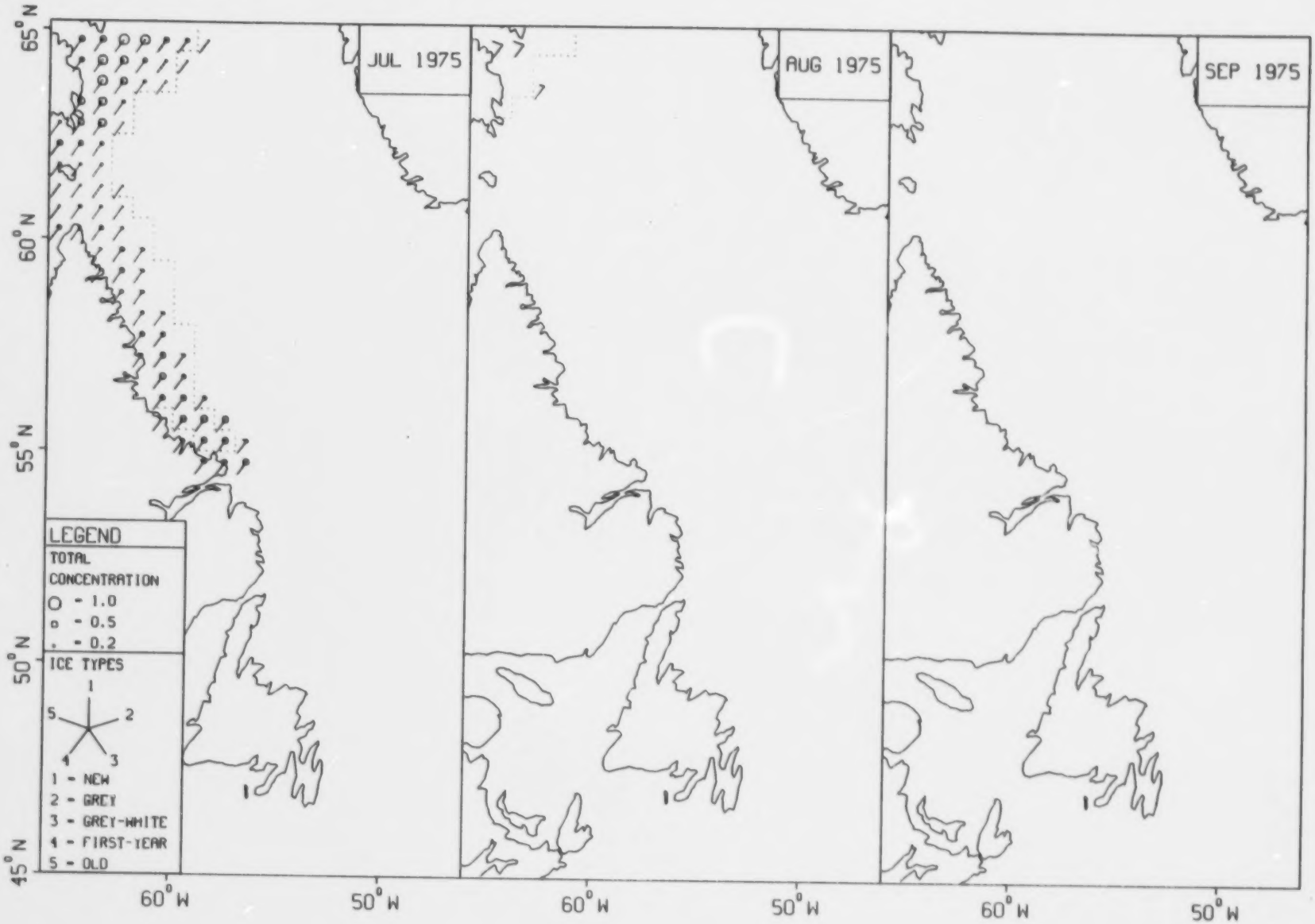
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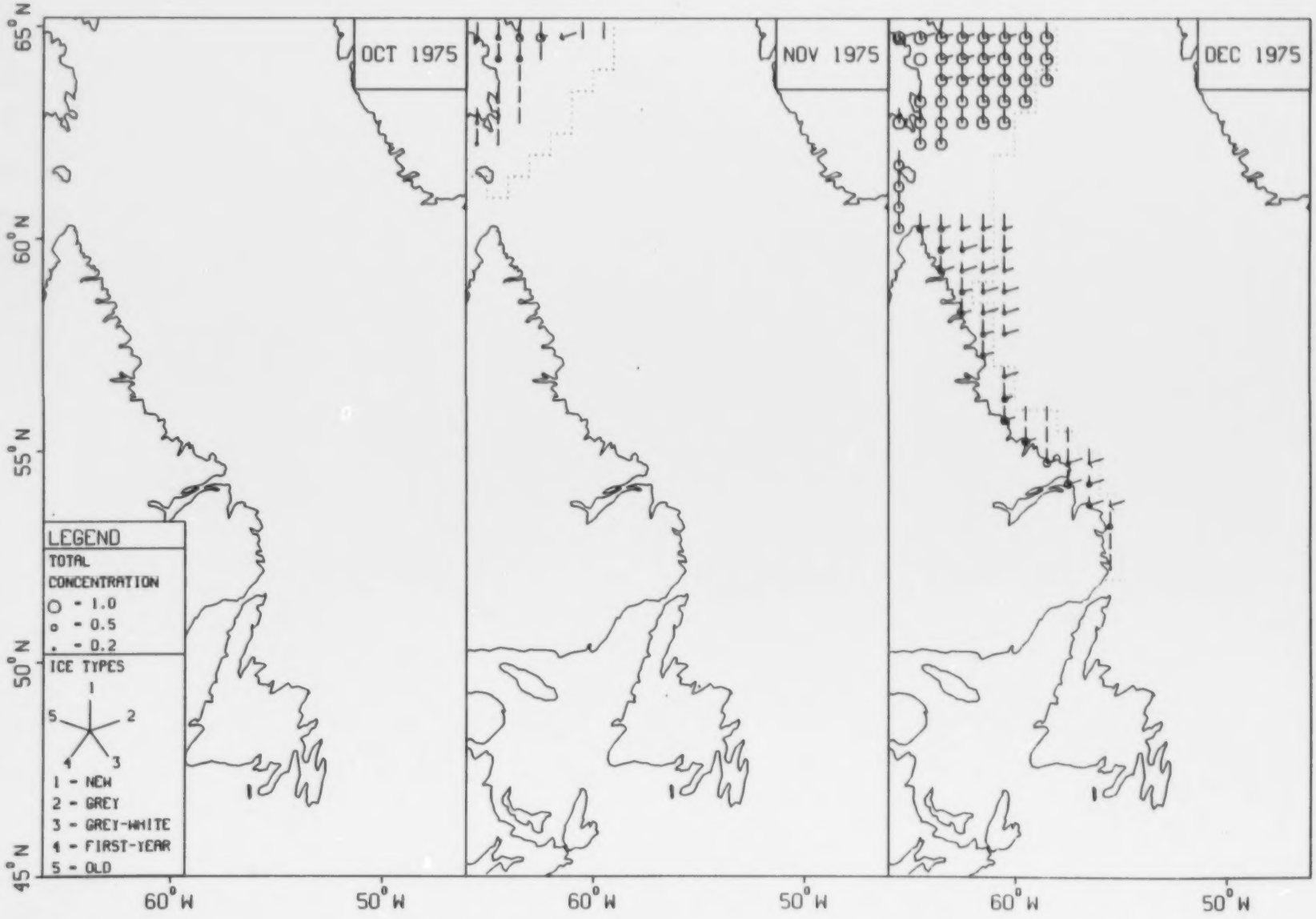
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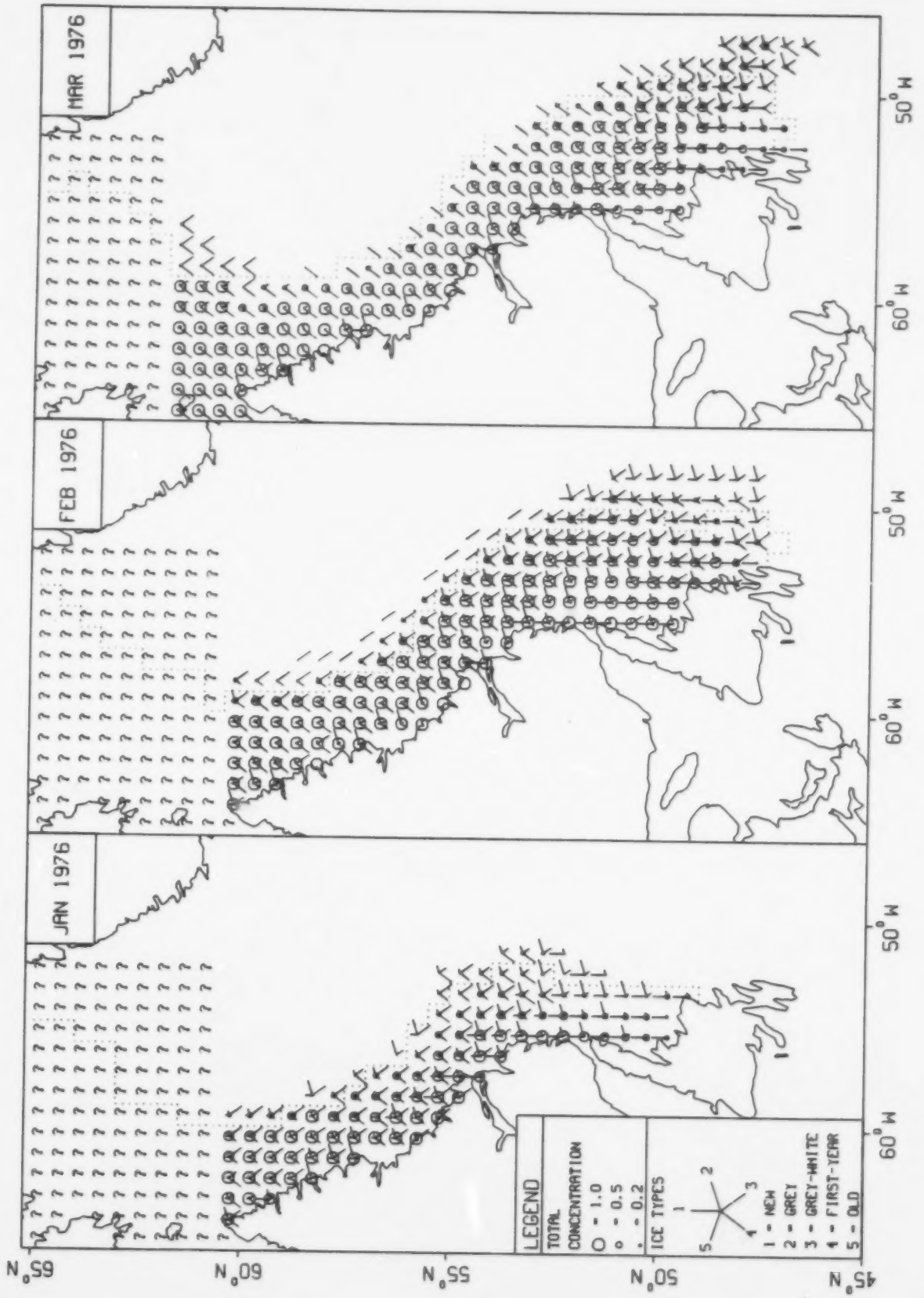
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ICE TYPES
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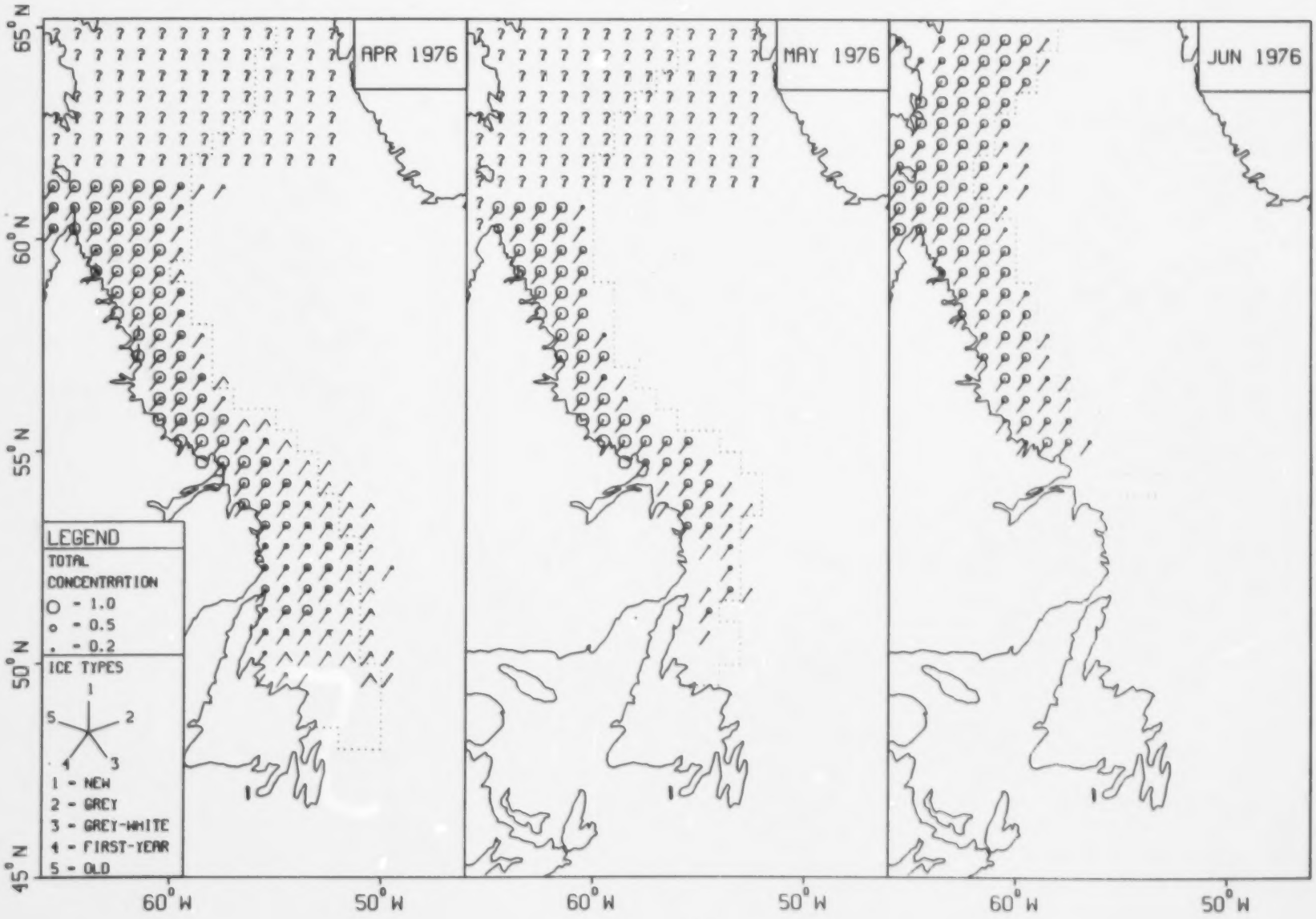
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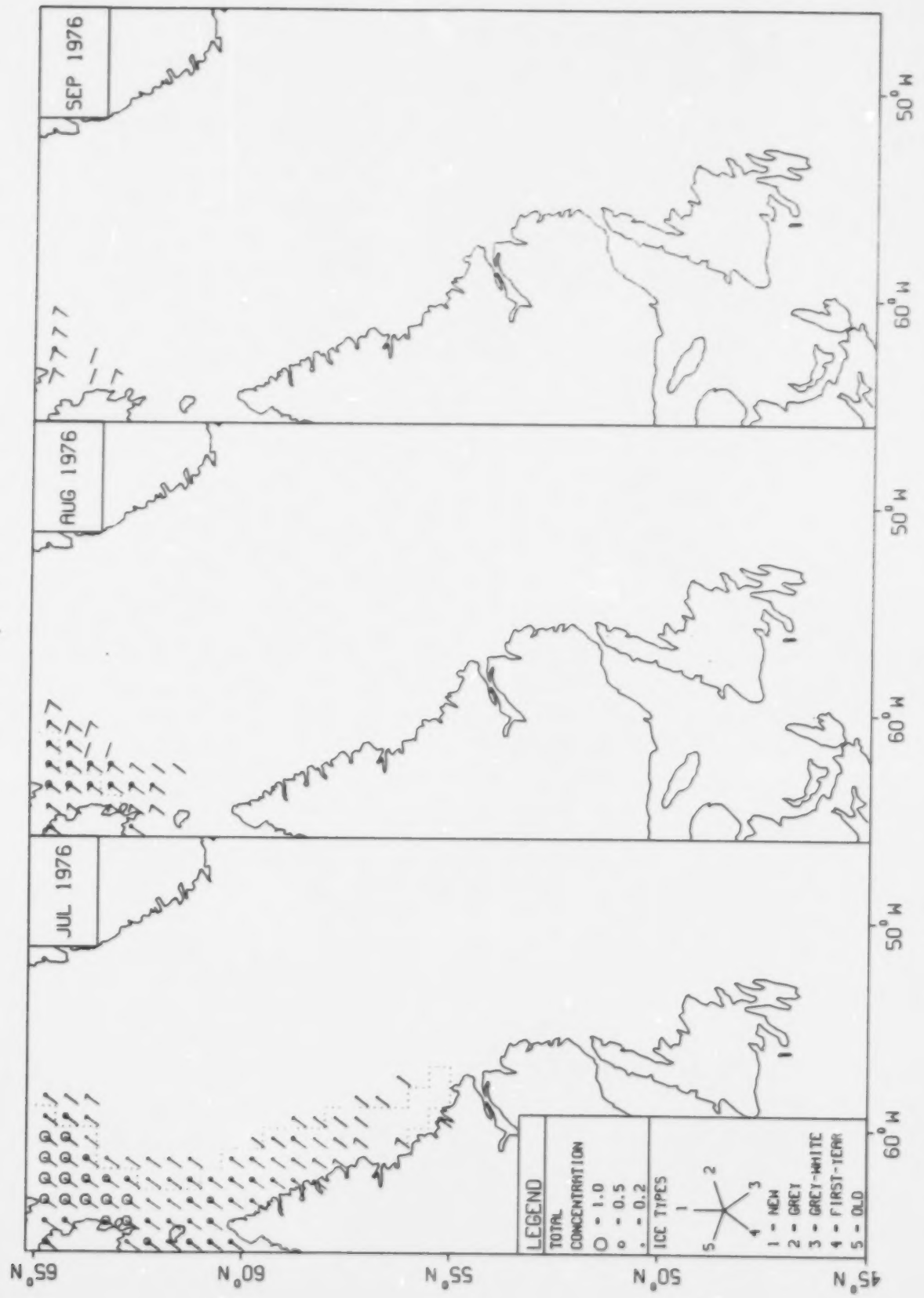
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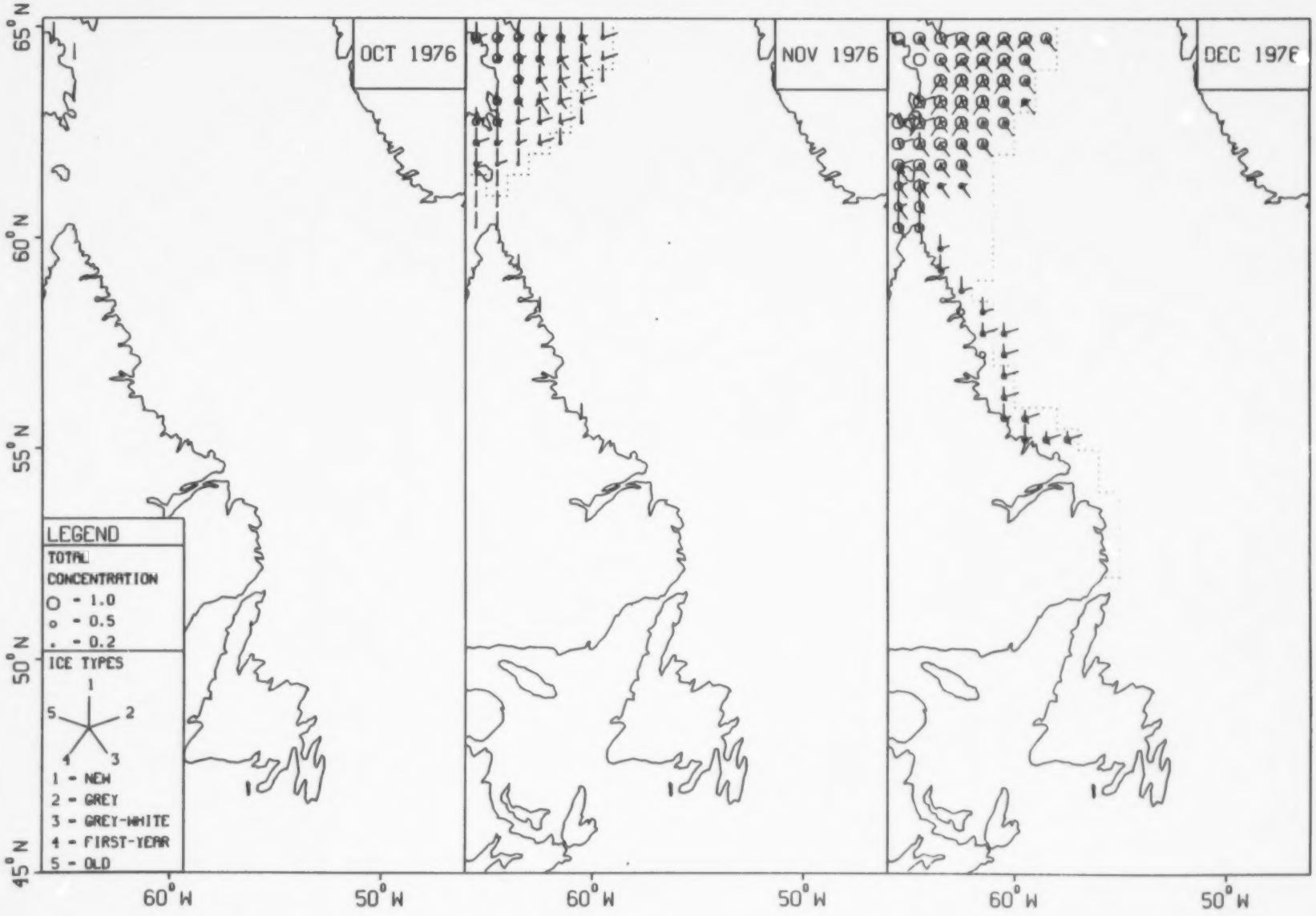
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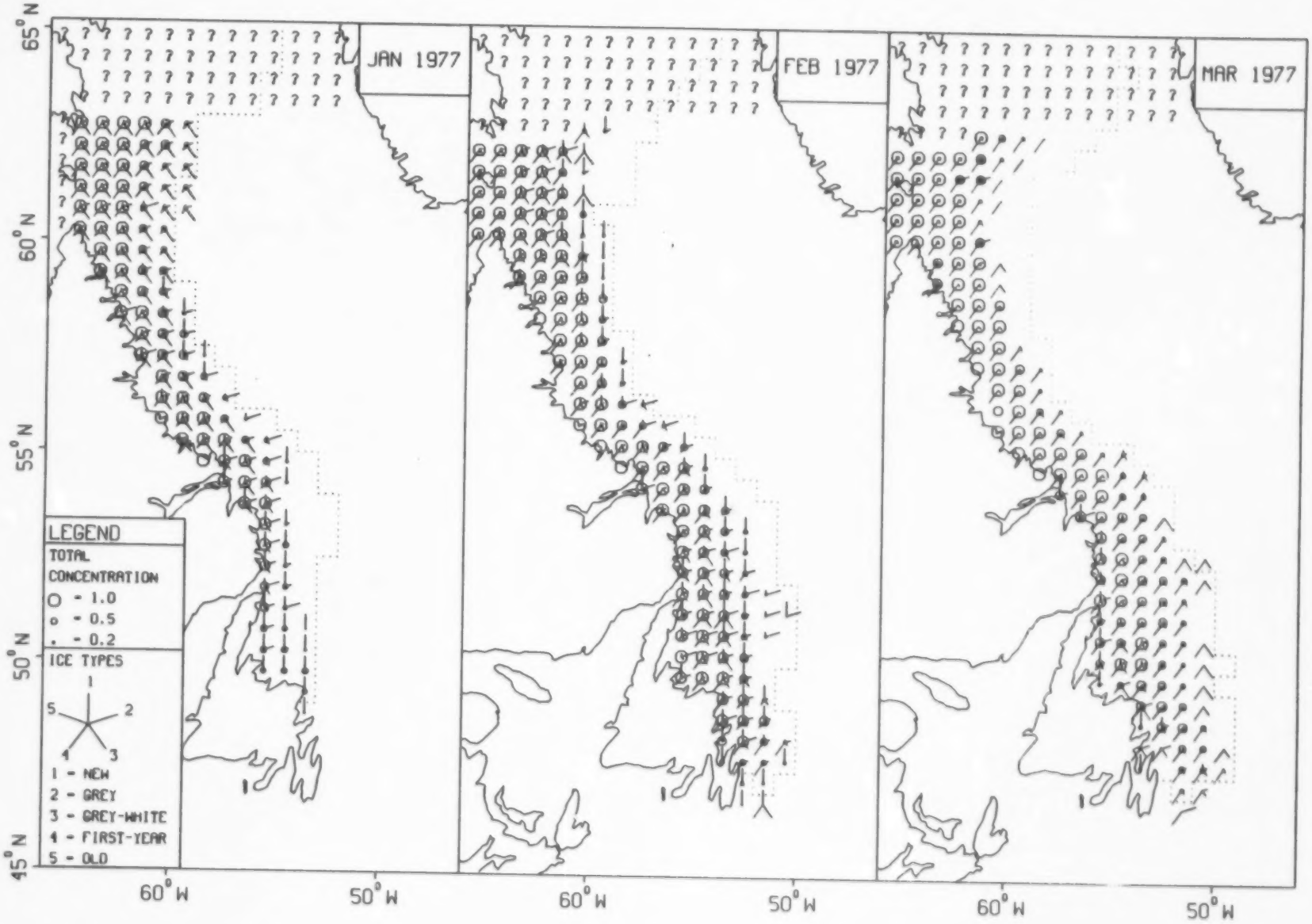
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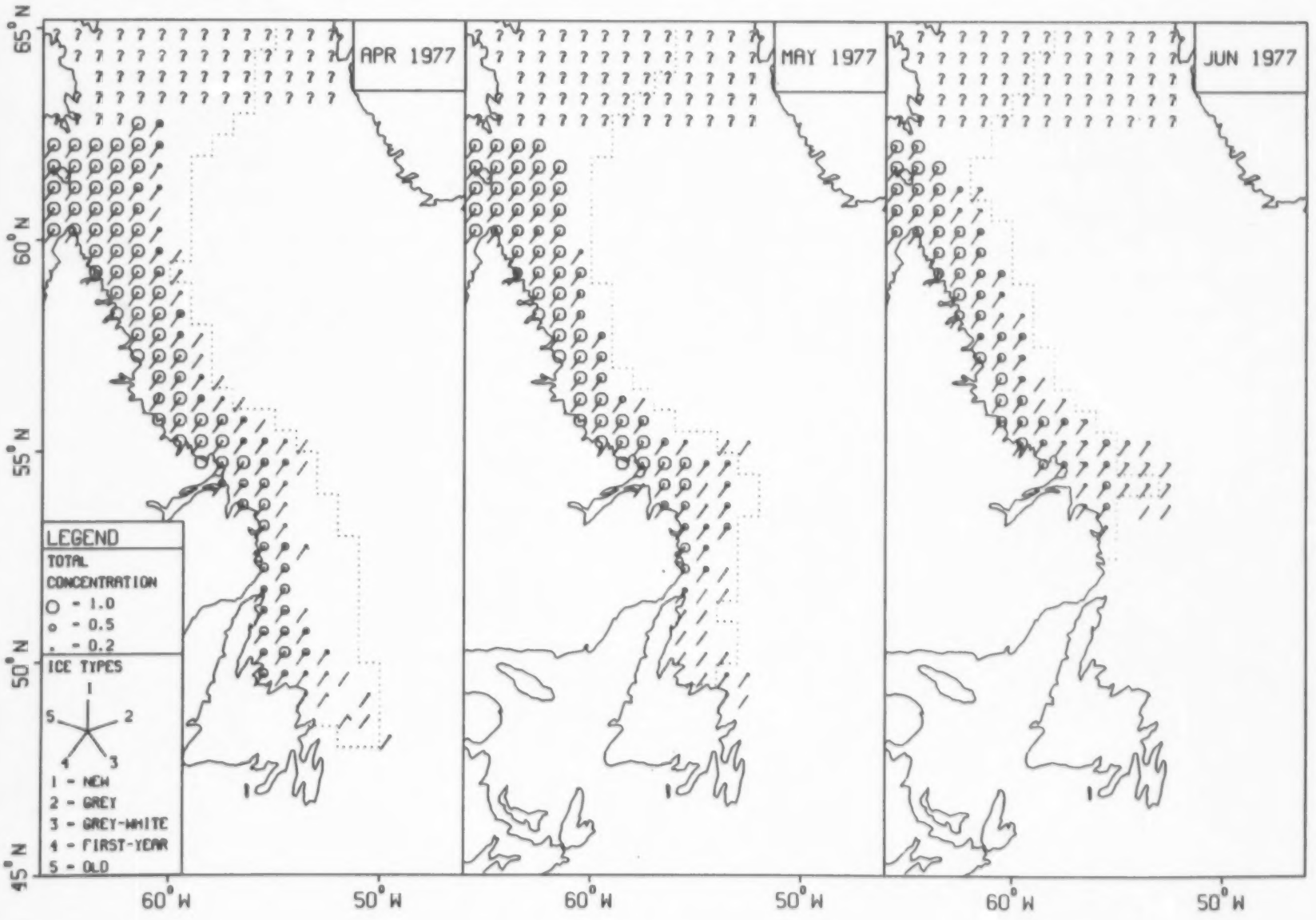
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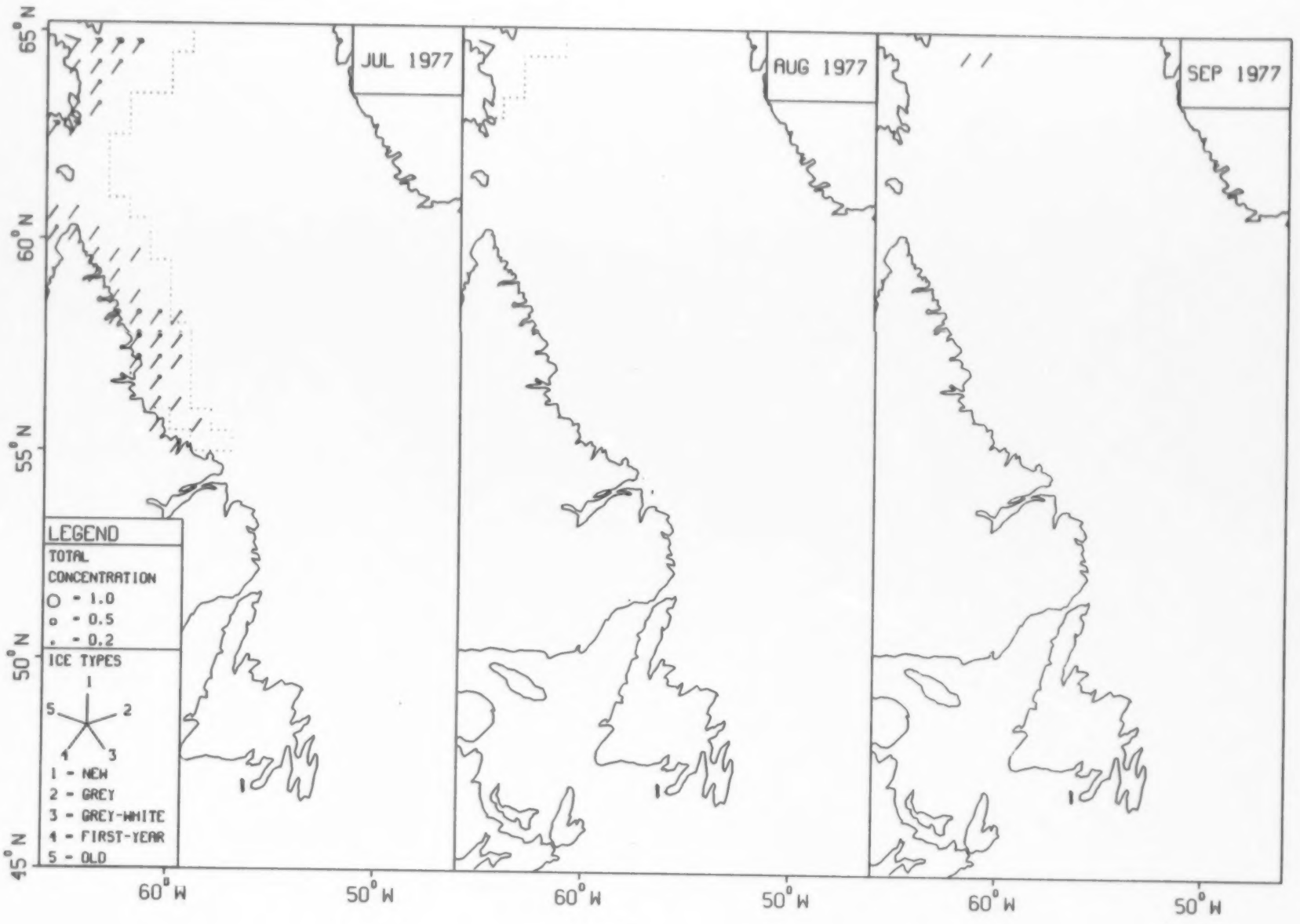
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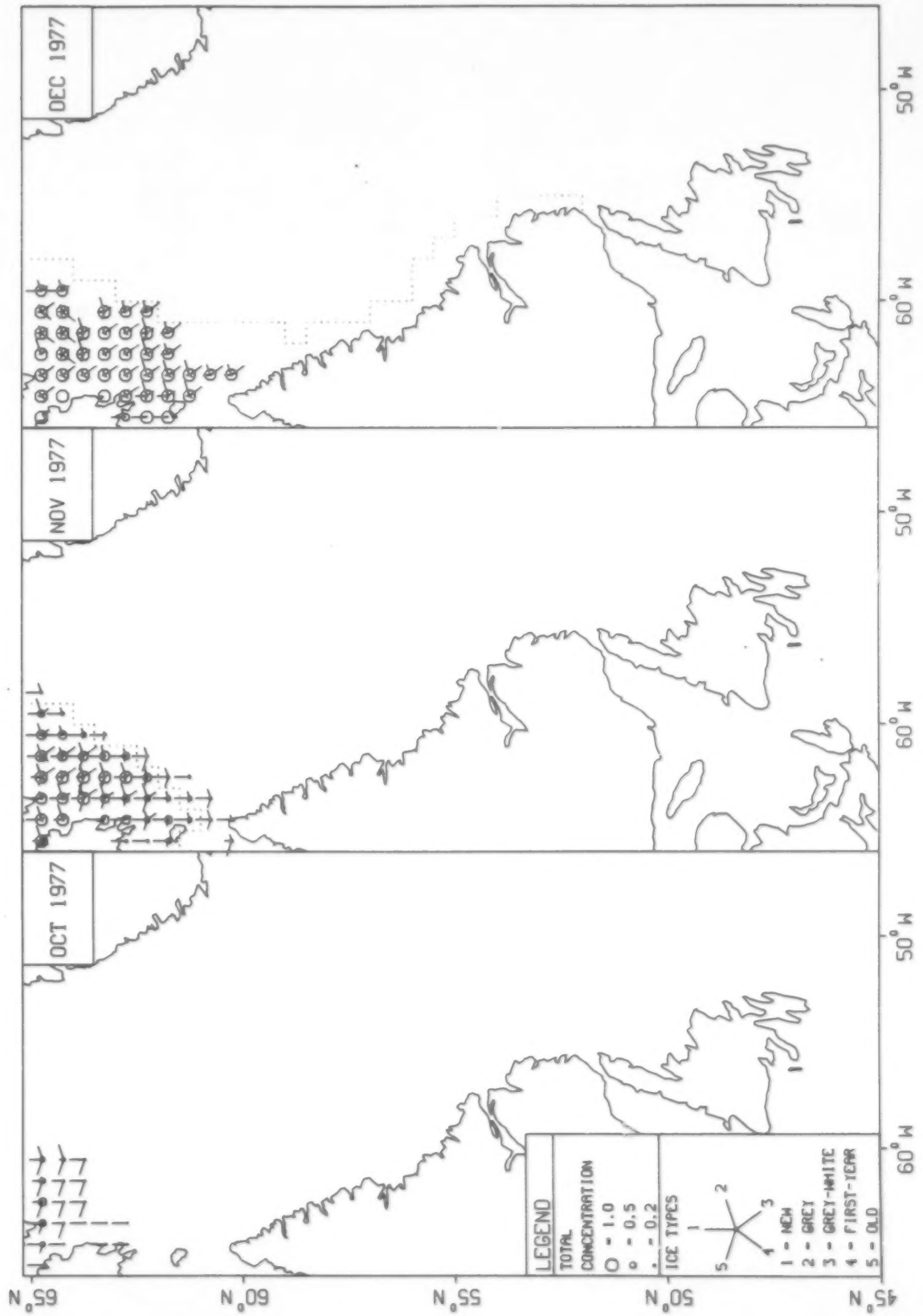
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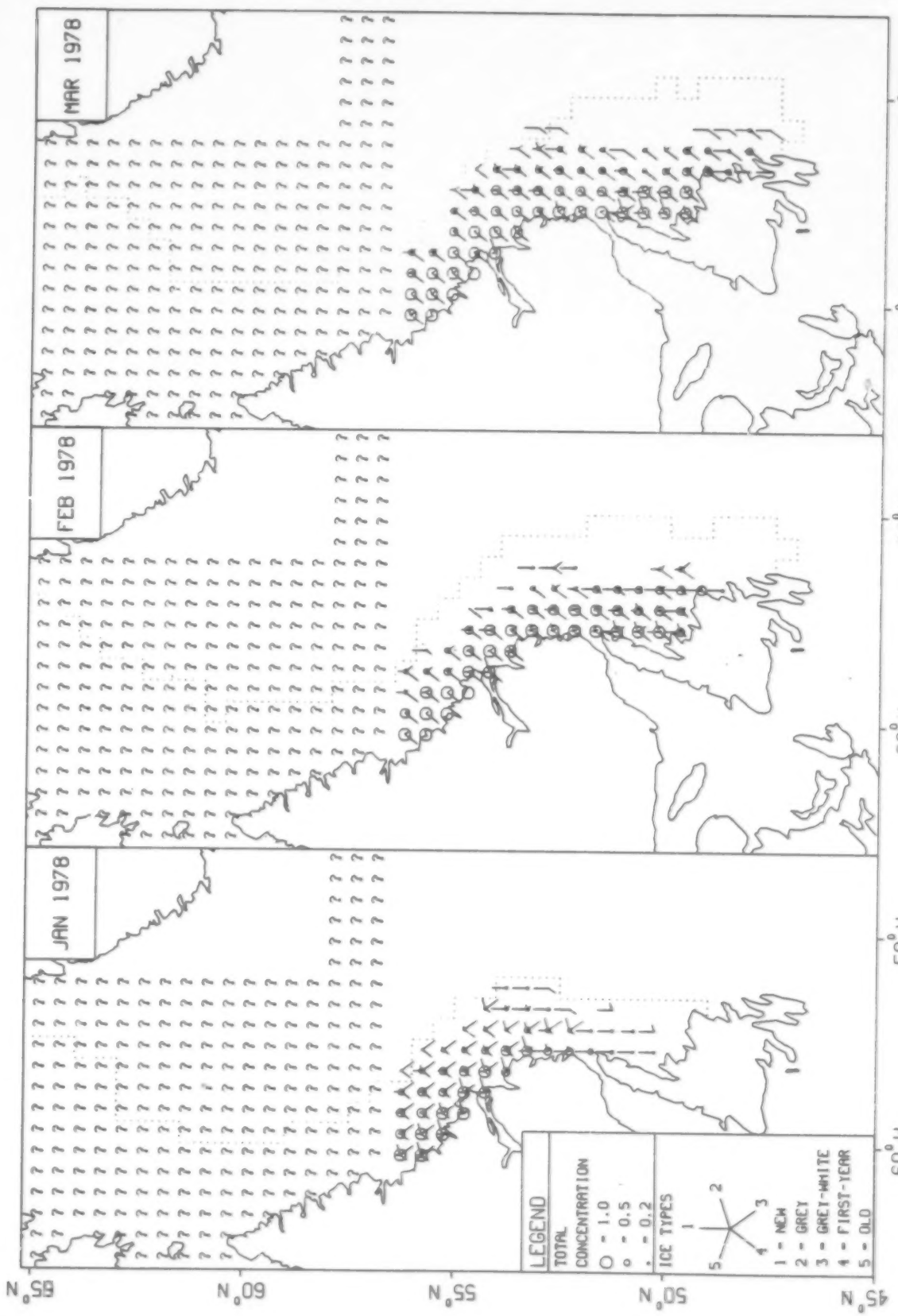
JAN 1978
FEB 1978
MAR 1978
LEGEND
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CONCENTRATION
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. - 0.2
ICE TYPES
1 - NEW
2 - GREY
3 - GREY-WHITE
4 - FIRST-YEAR
5 - OLD
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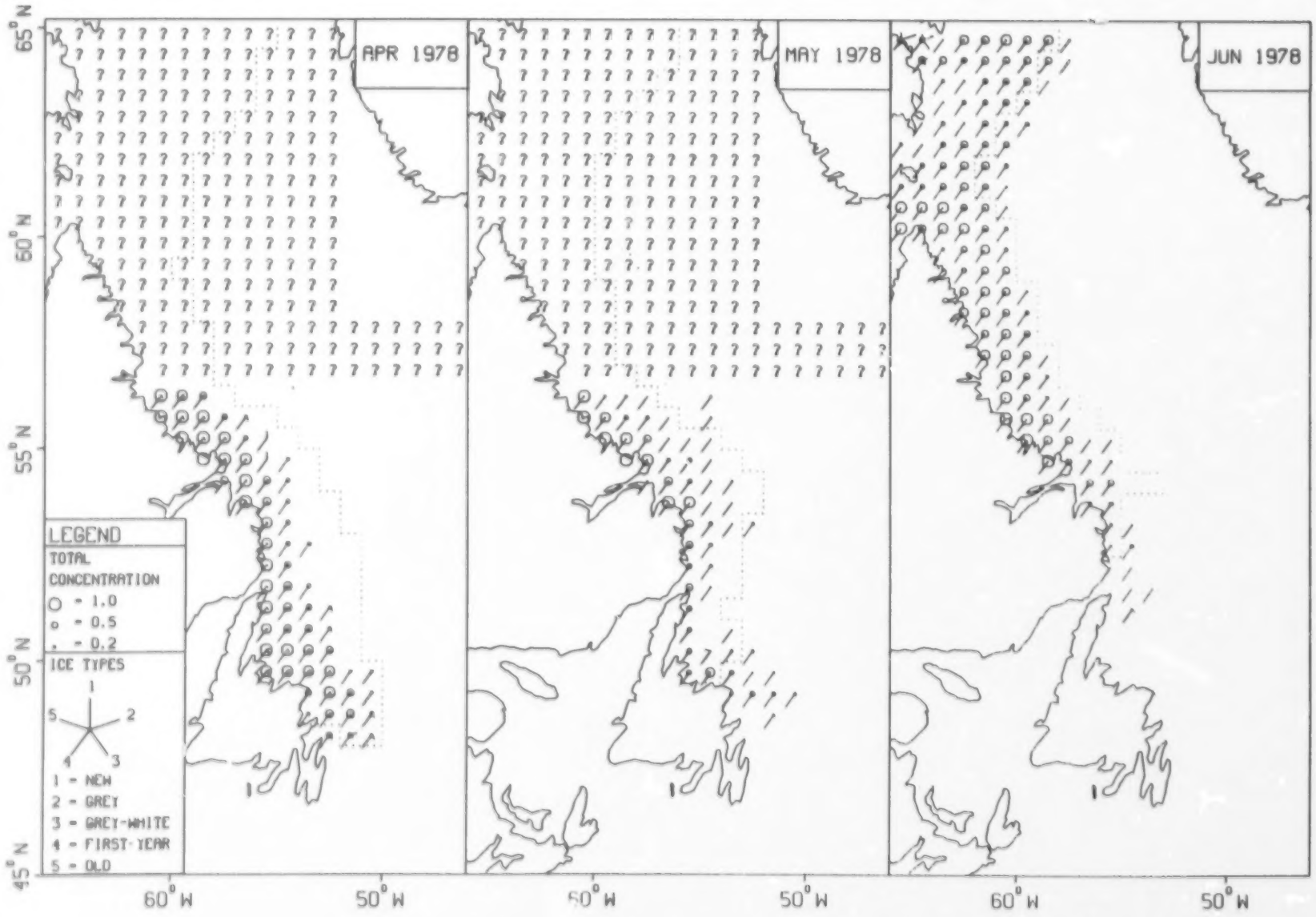
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LEGEND
TOTAL CONCENTRATION
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ICE TYPES
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3 - GREY-WHITE
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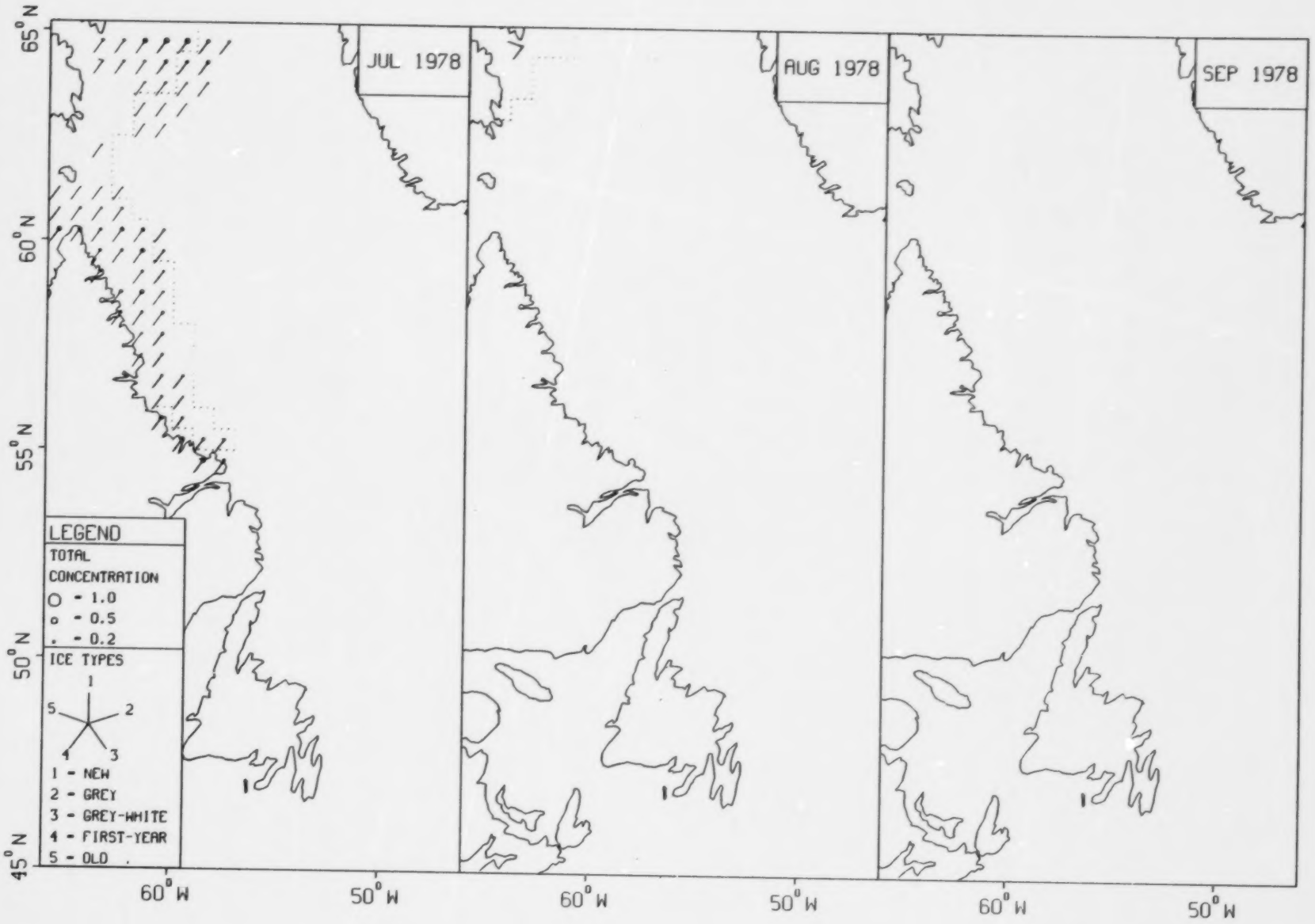
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LEGEND
TOTAL CONCENTRATION
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ICE TYPES
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4 - FIRST-YEAR
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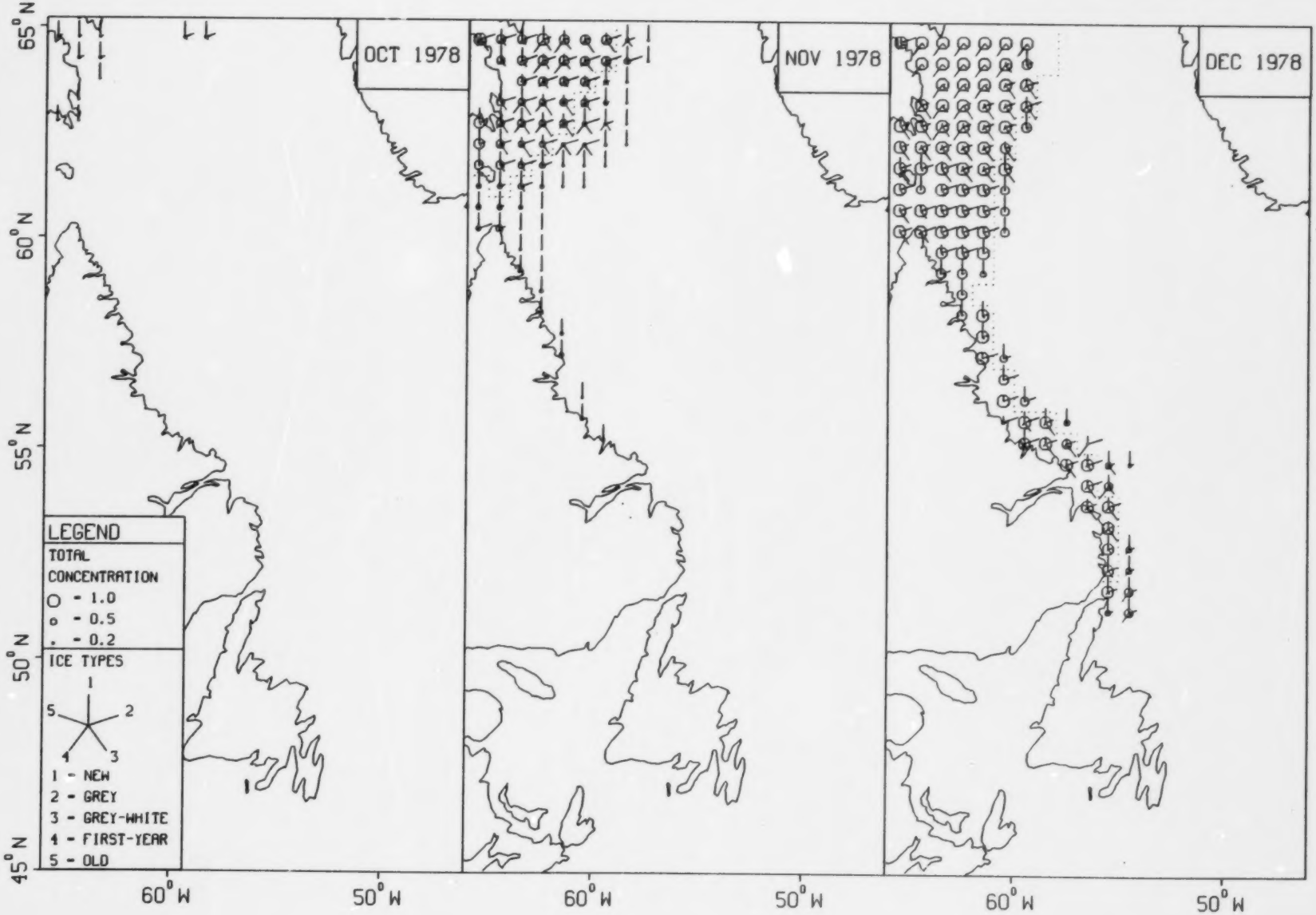
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ICE TYPES
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3 - GREY-WHITE
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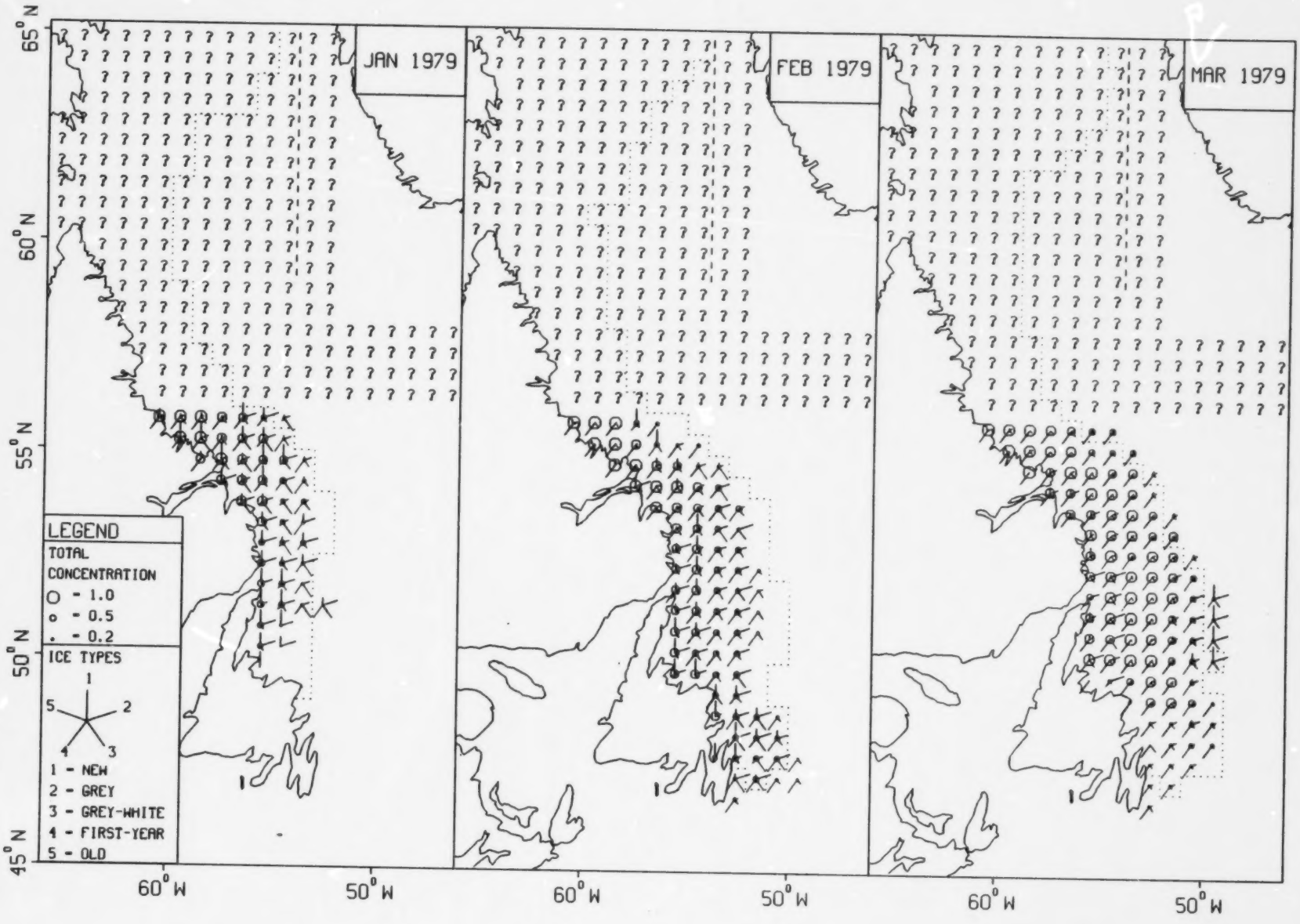
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CONCENTRATION
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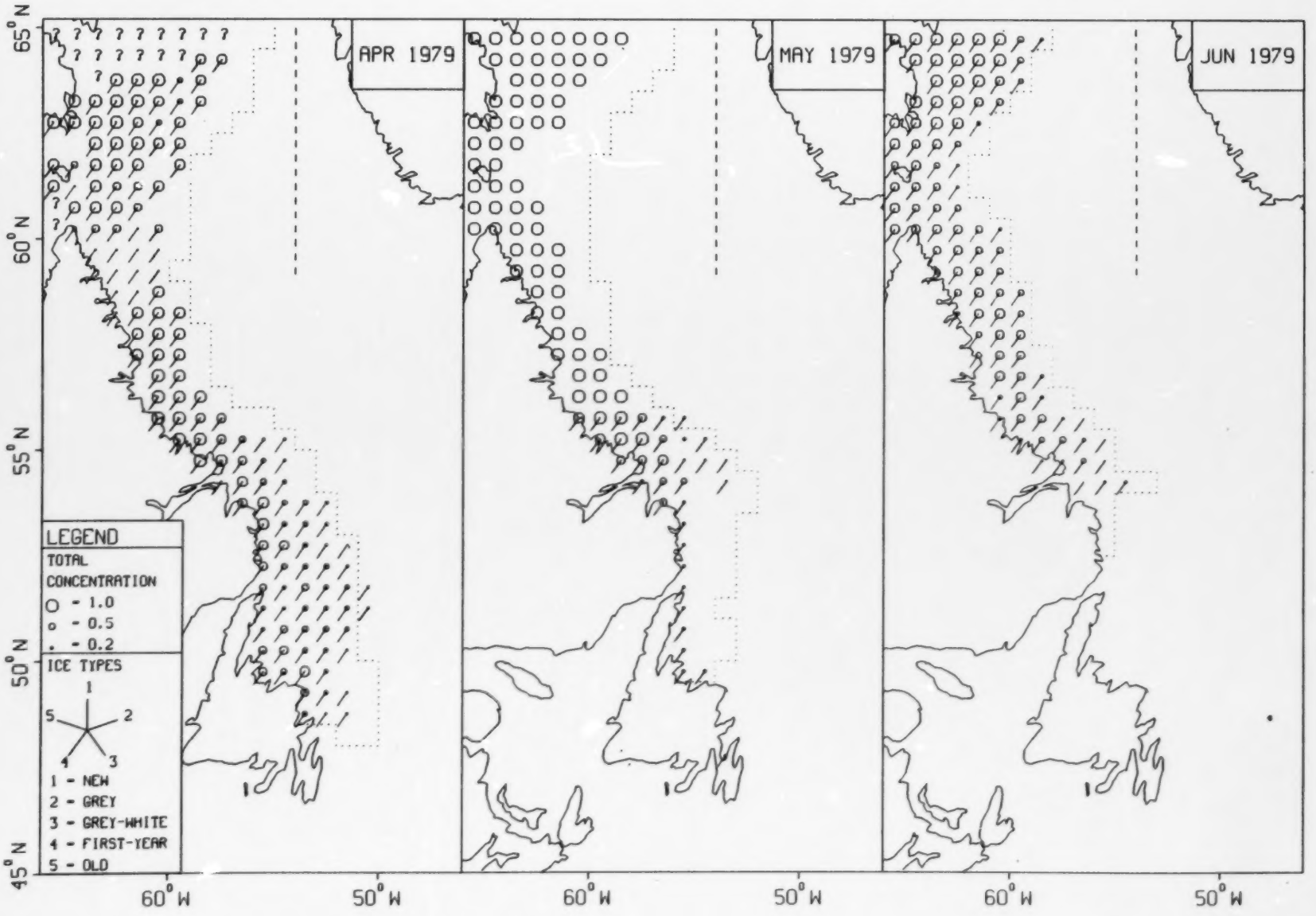
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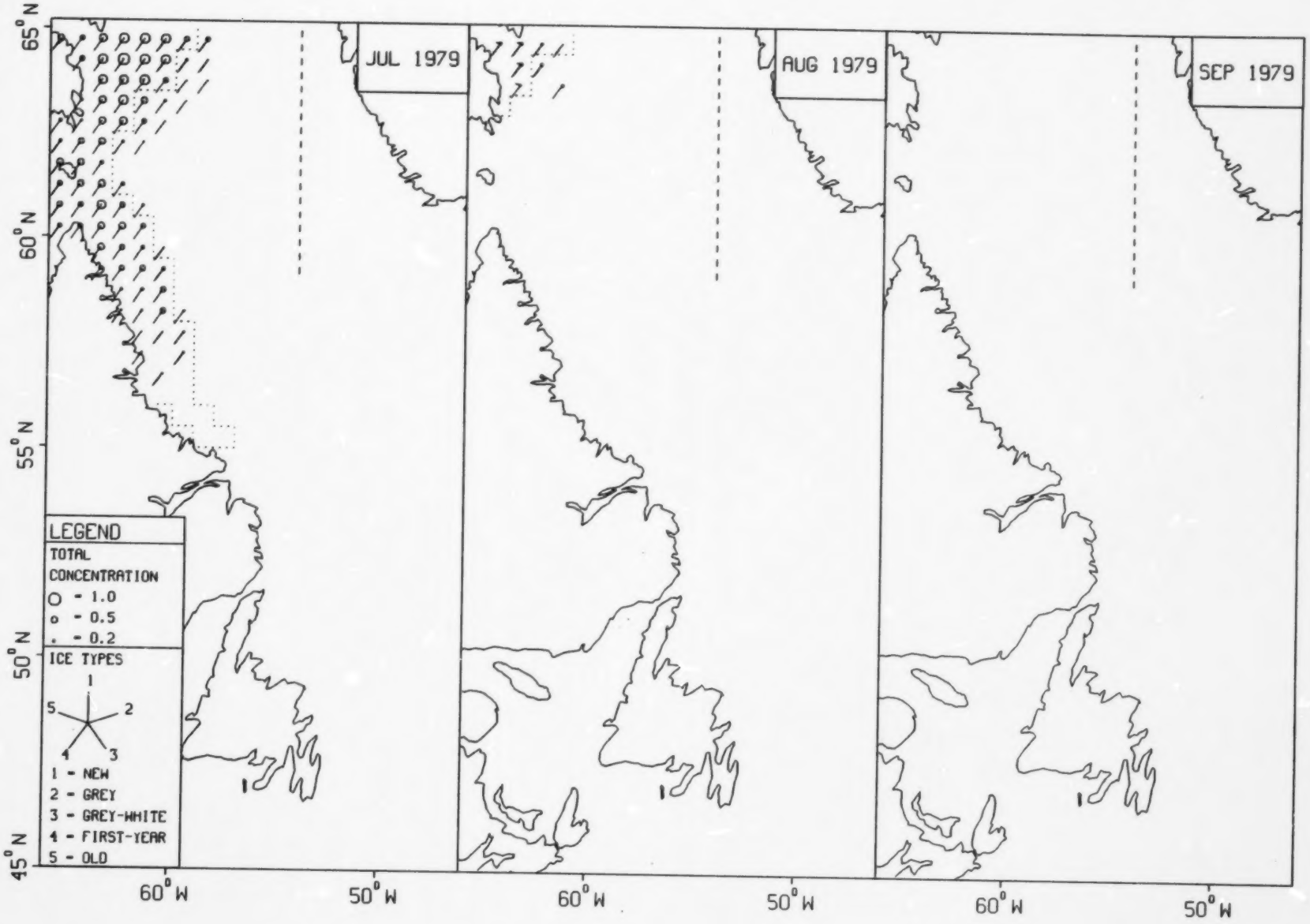
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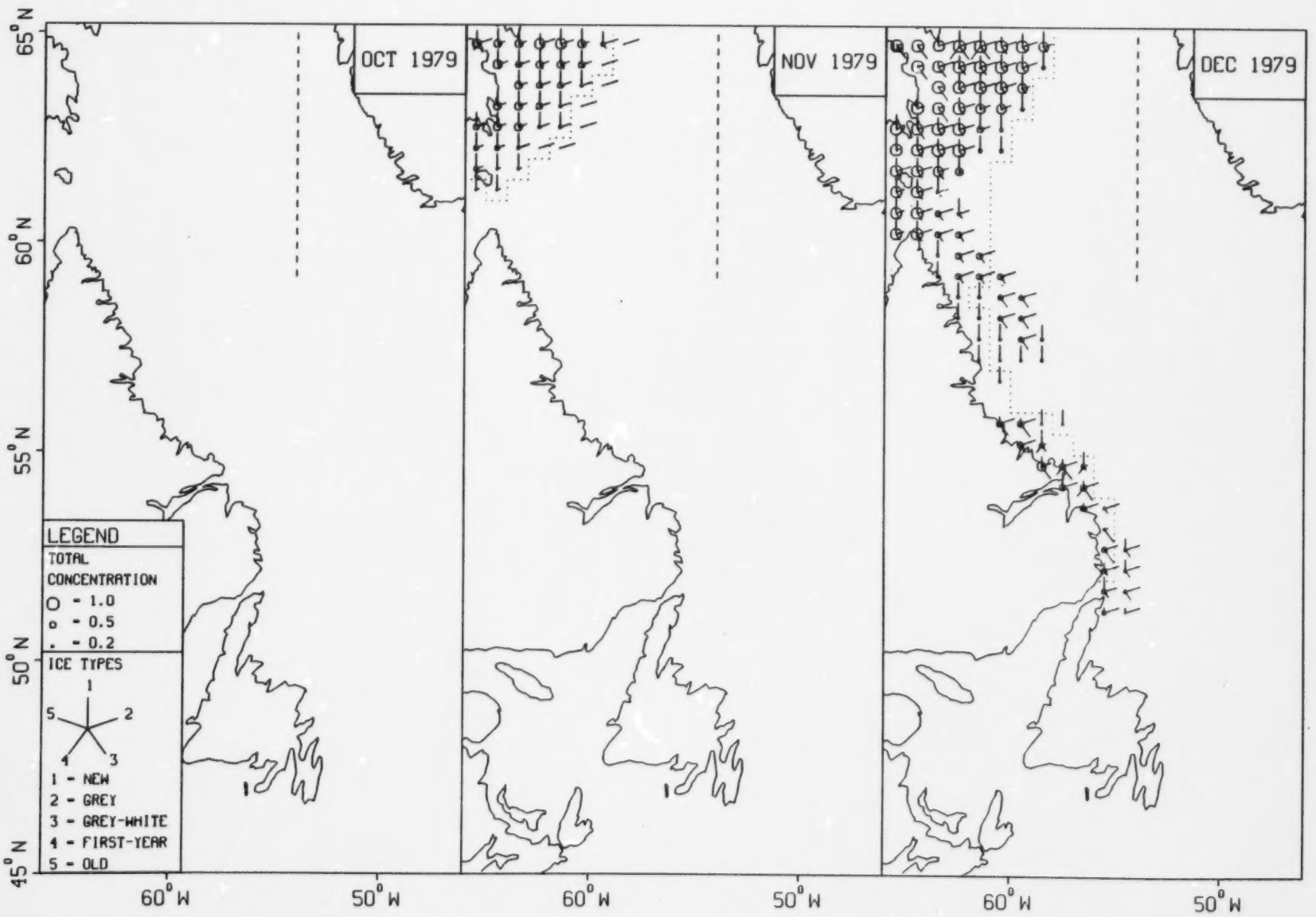
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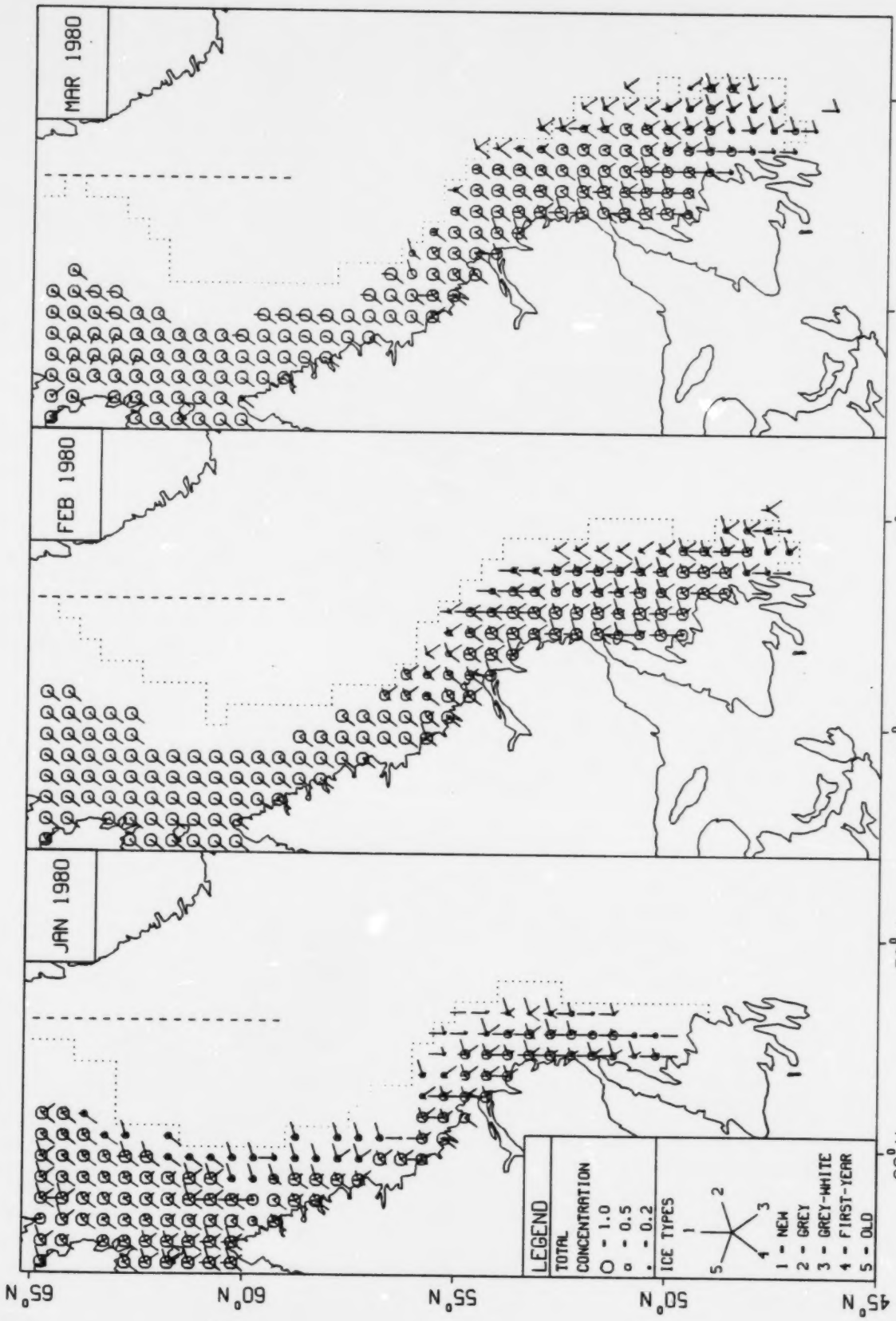
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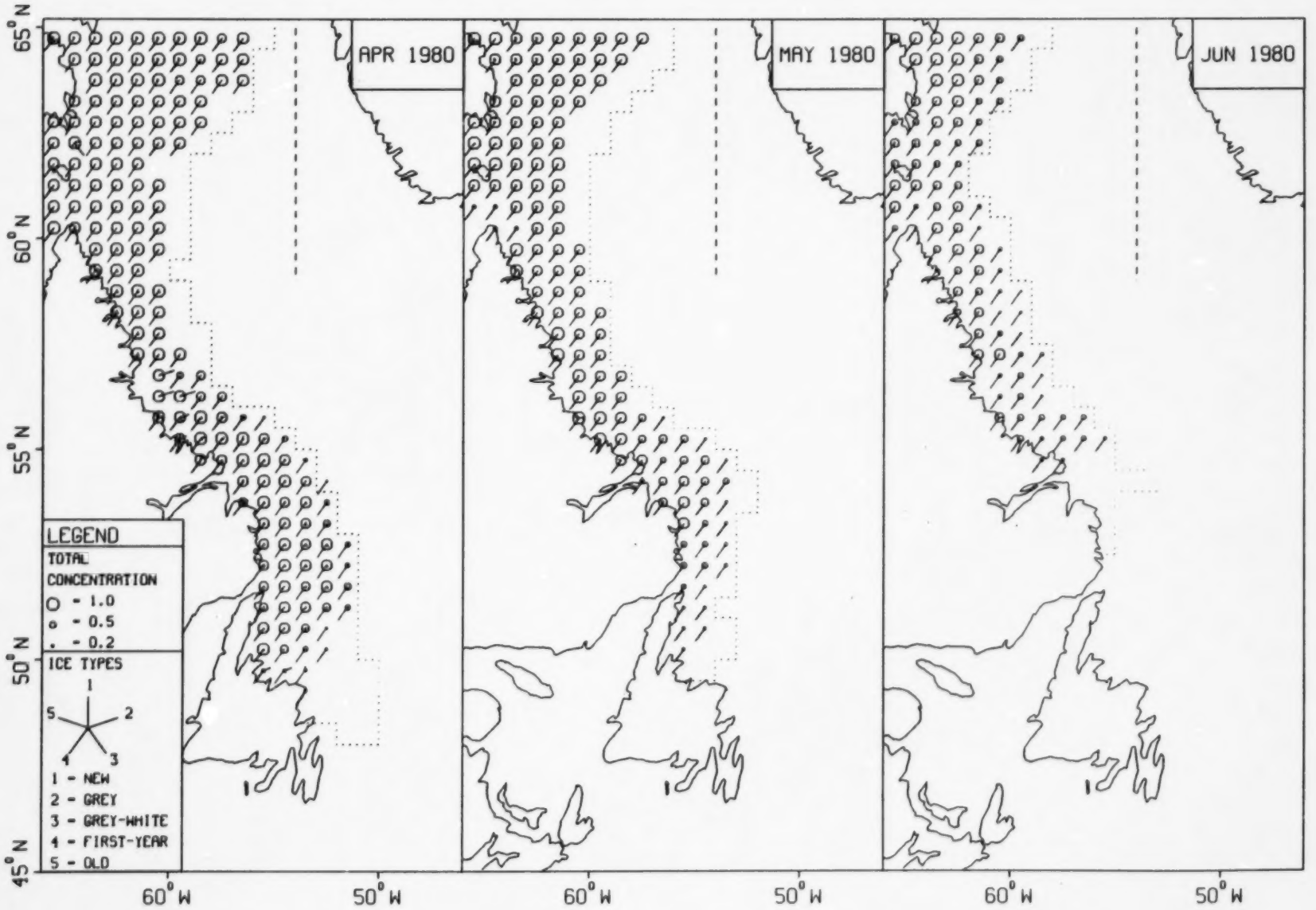
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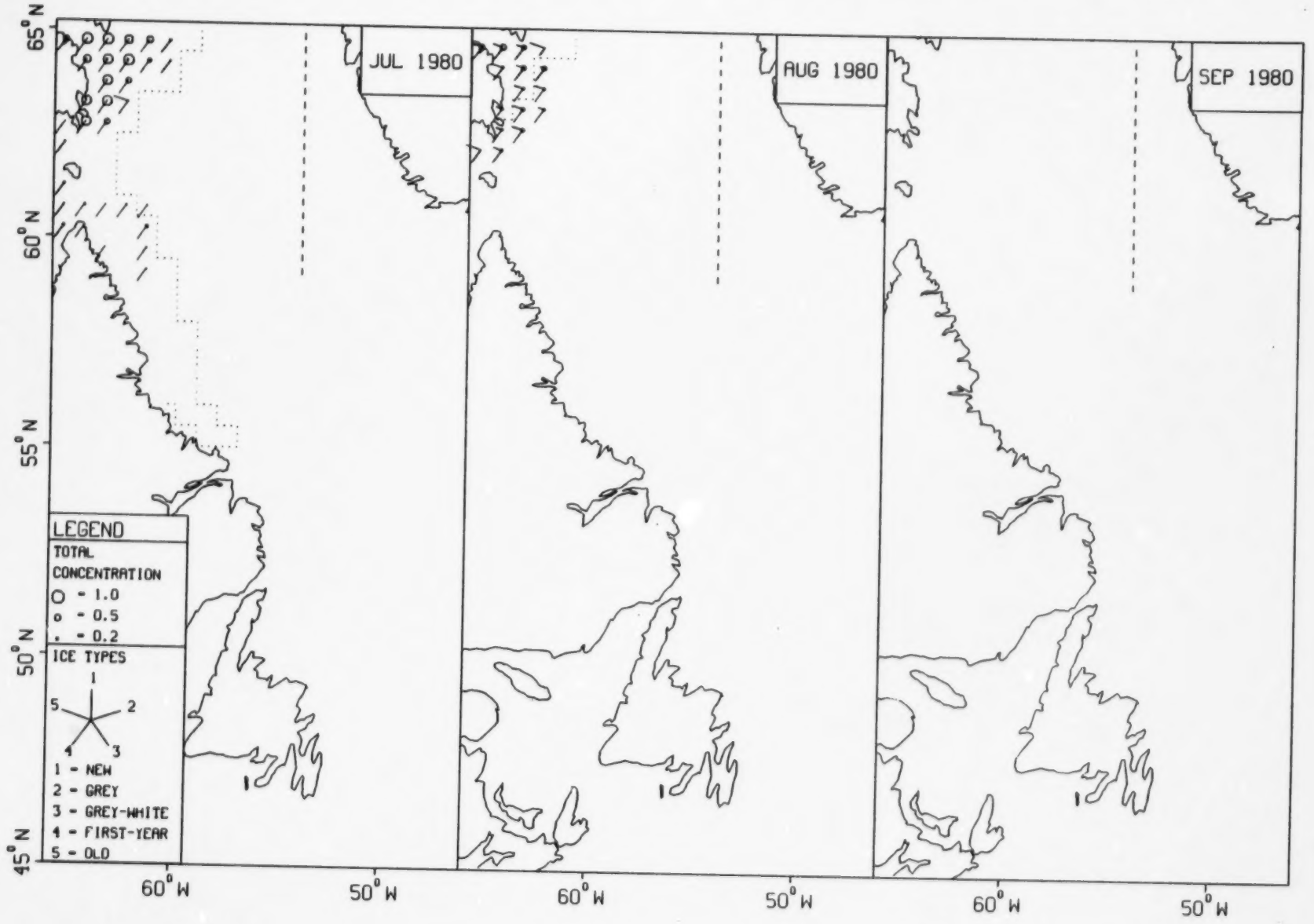
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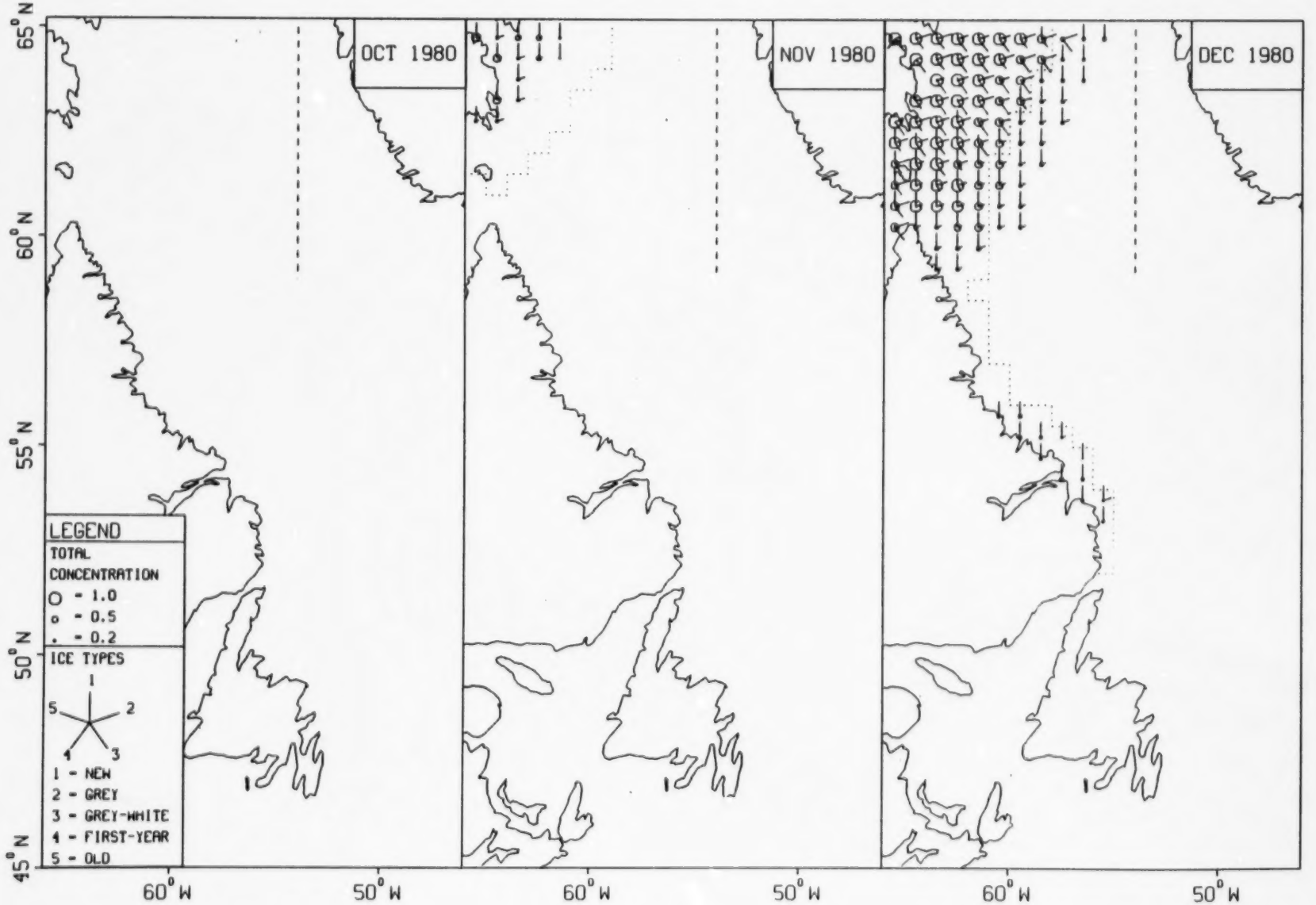
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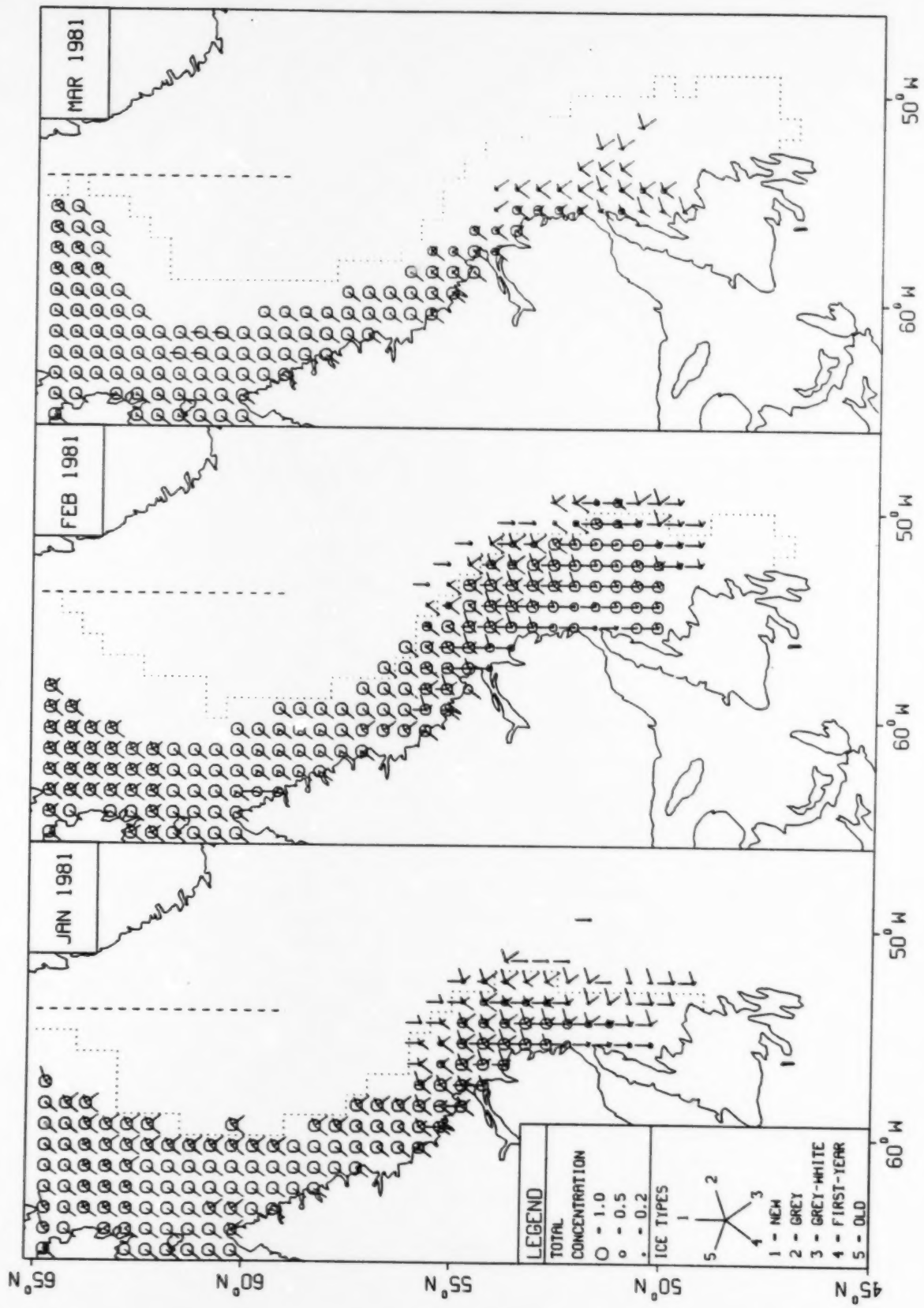
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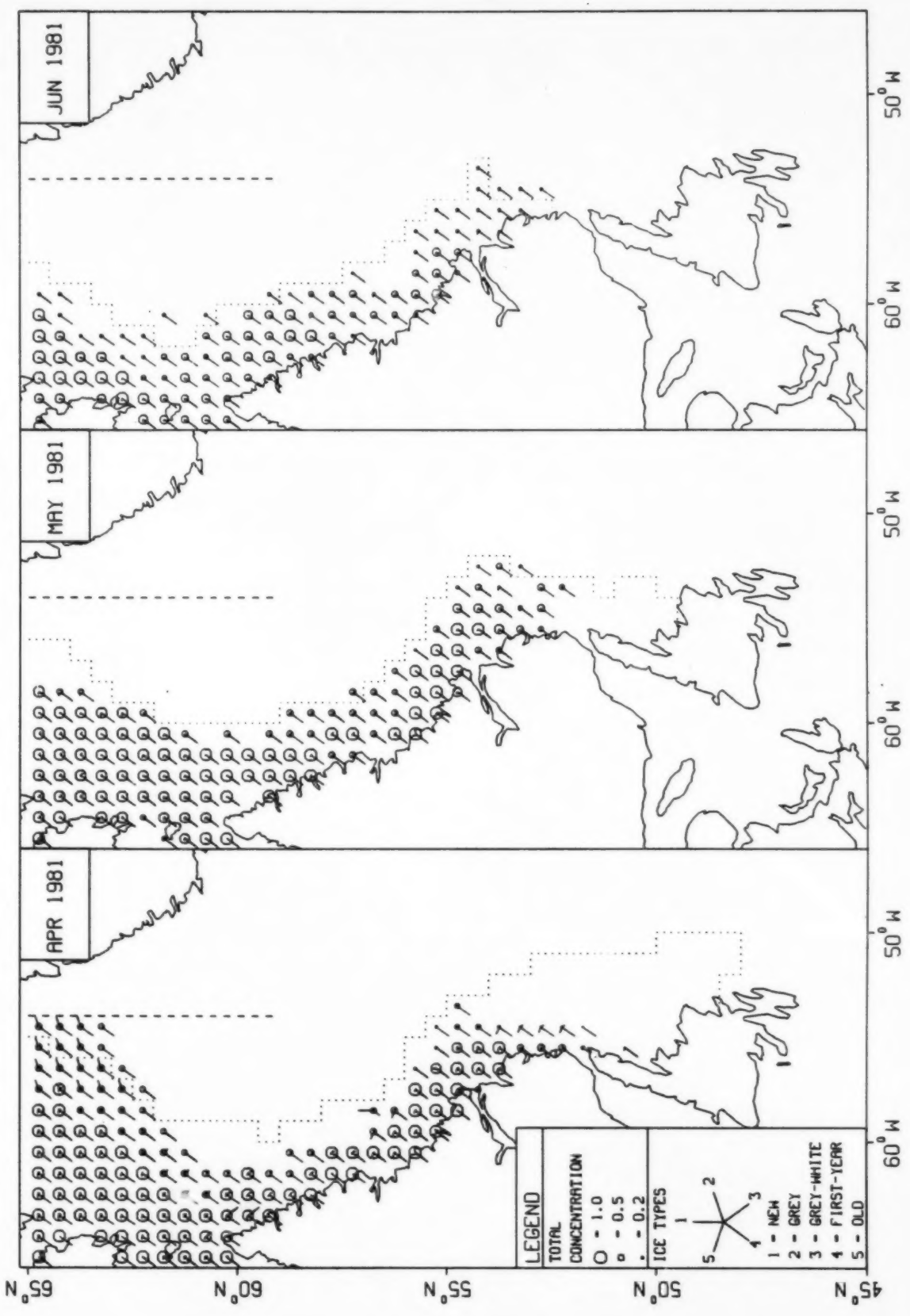
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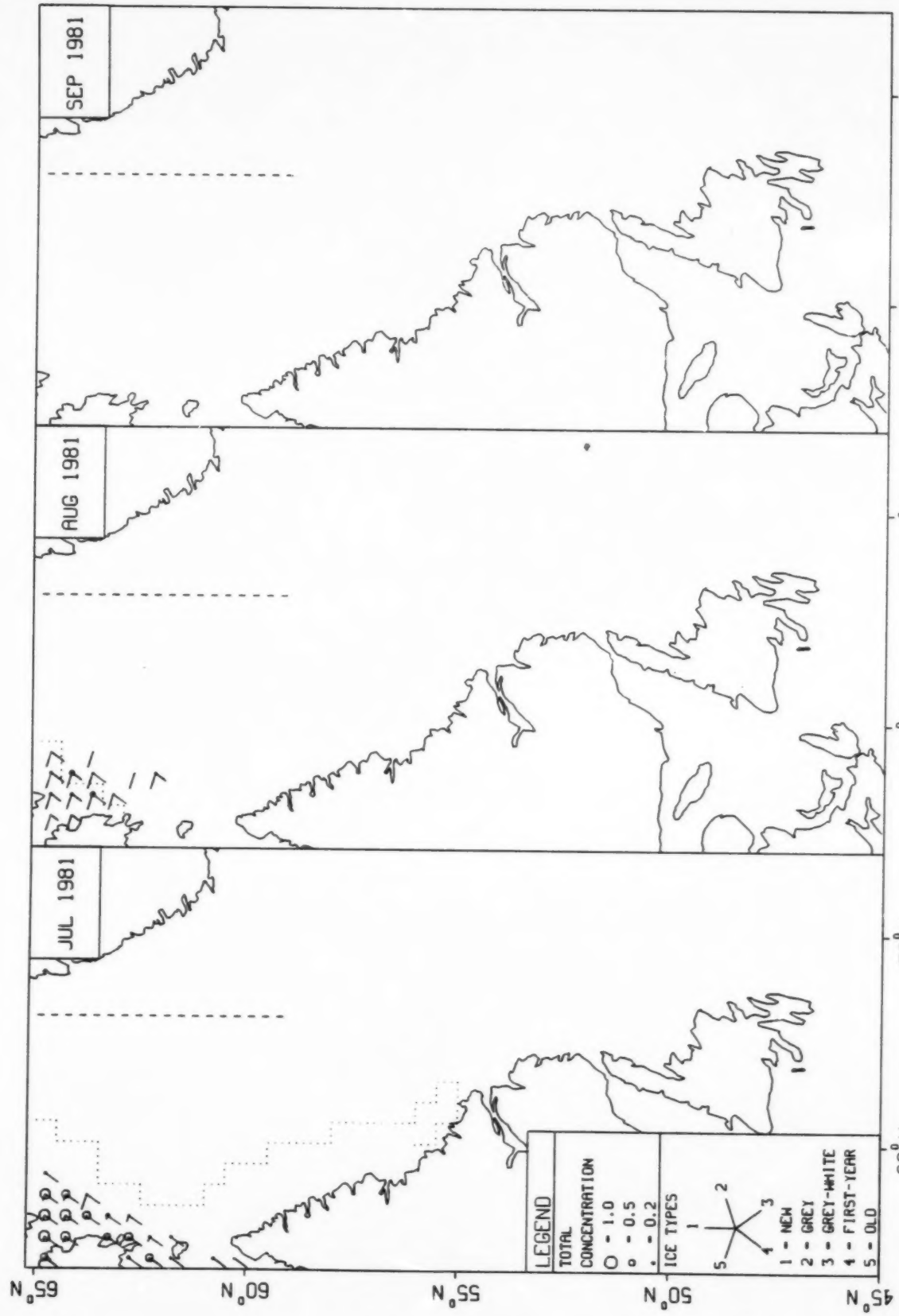
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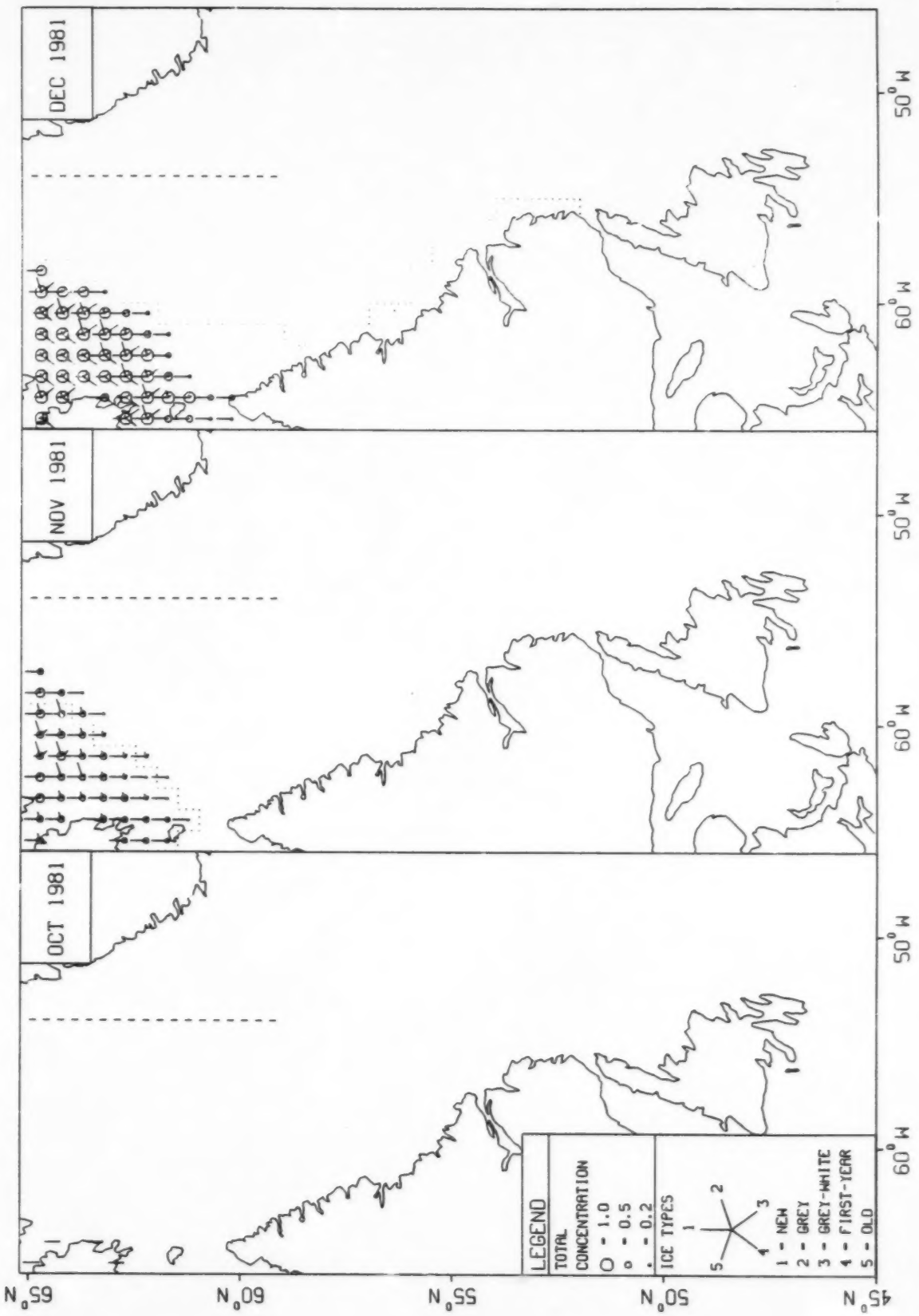
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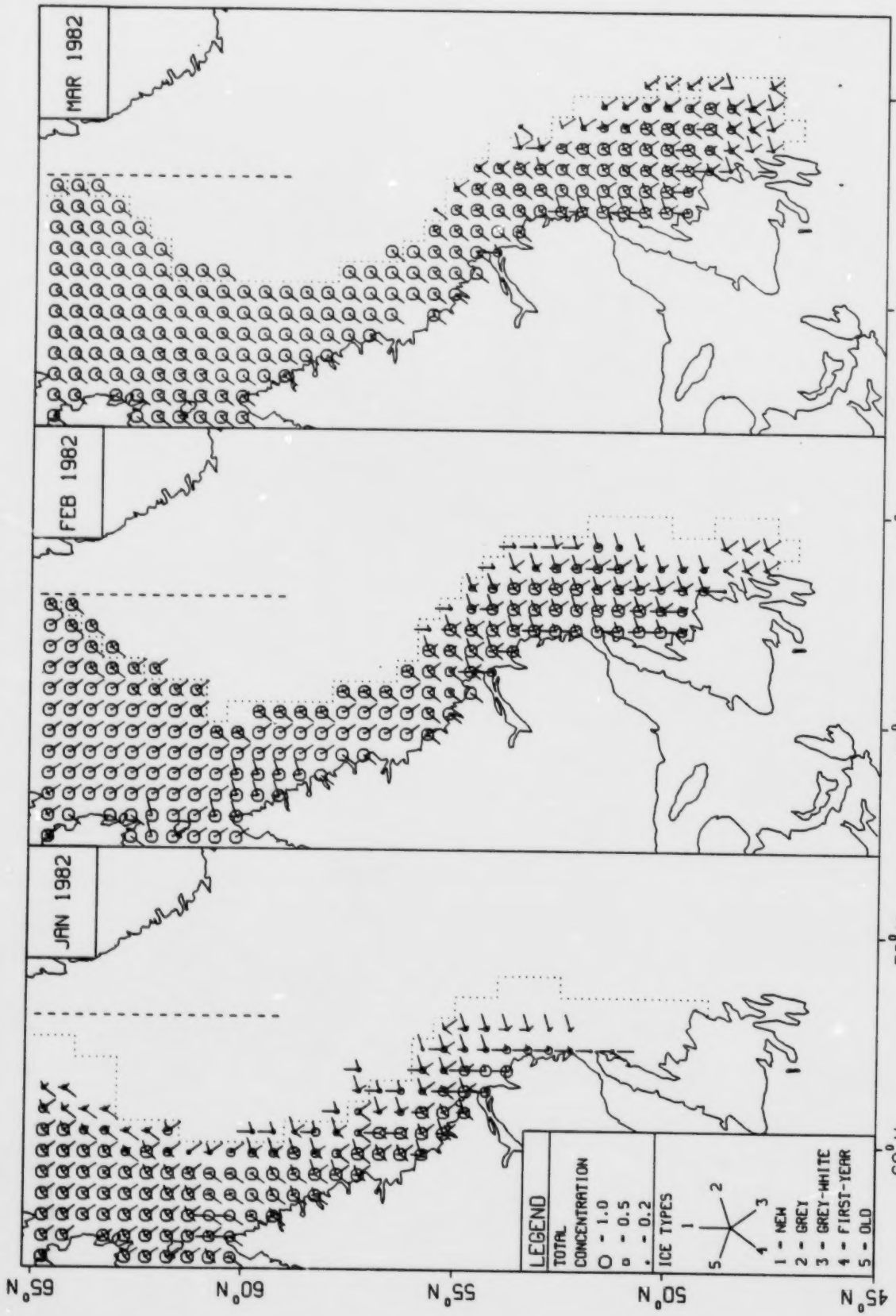
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ICE TYPES
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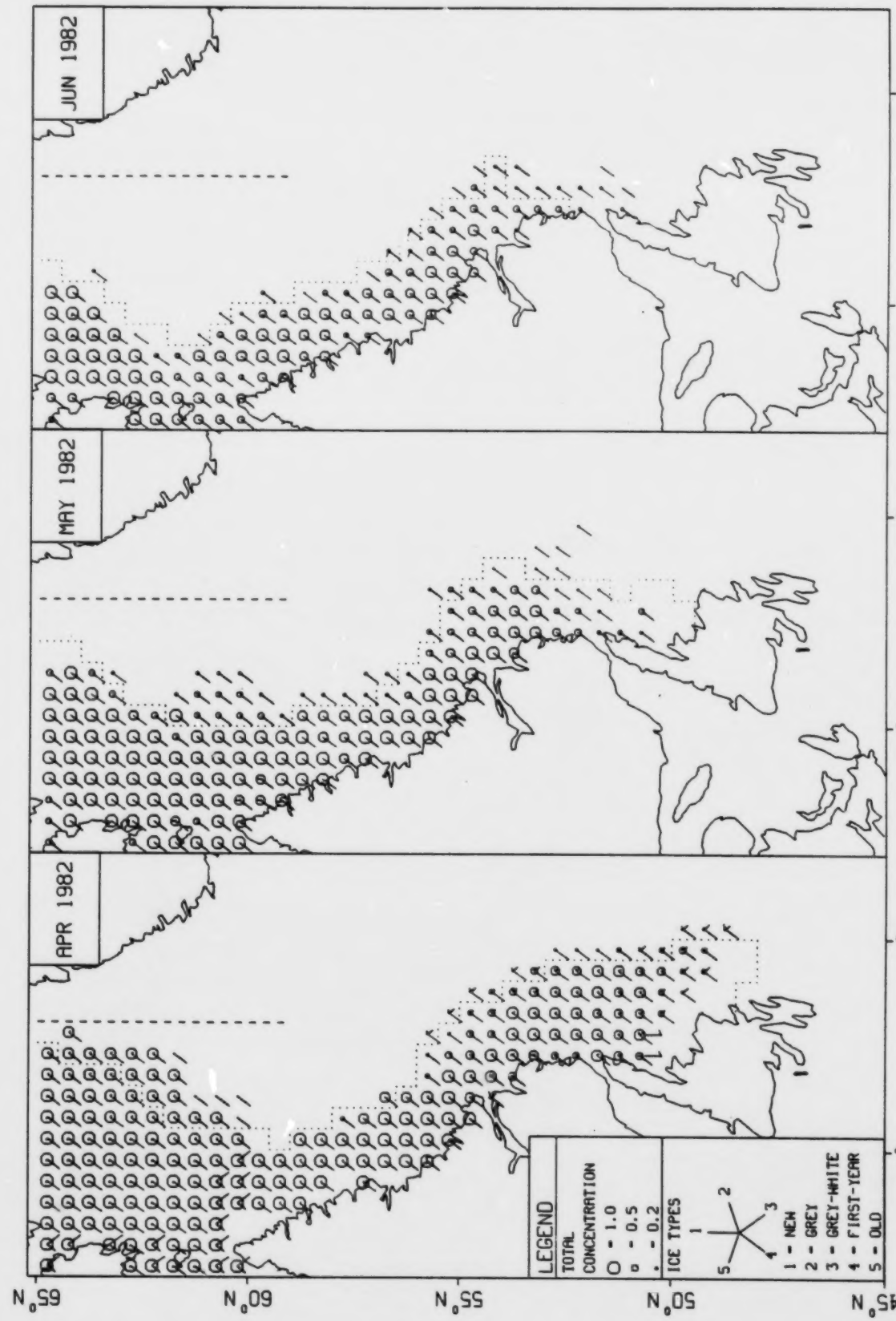
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LEGEND
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ICE TYPES
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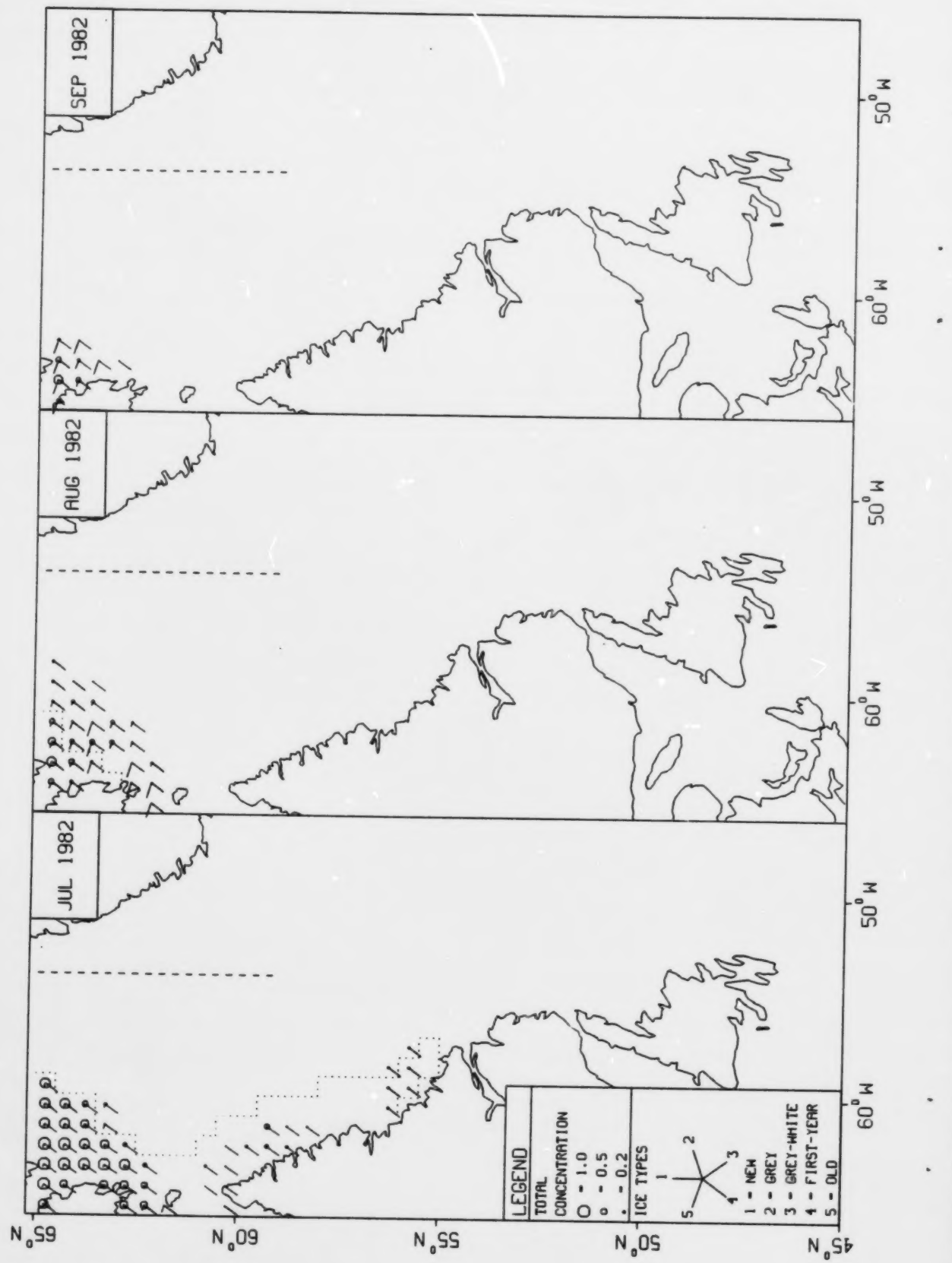
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LEGEND
TOTAL CONCENTRATION
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ICE TYPES
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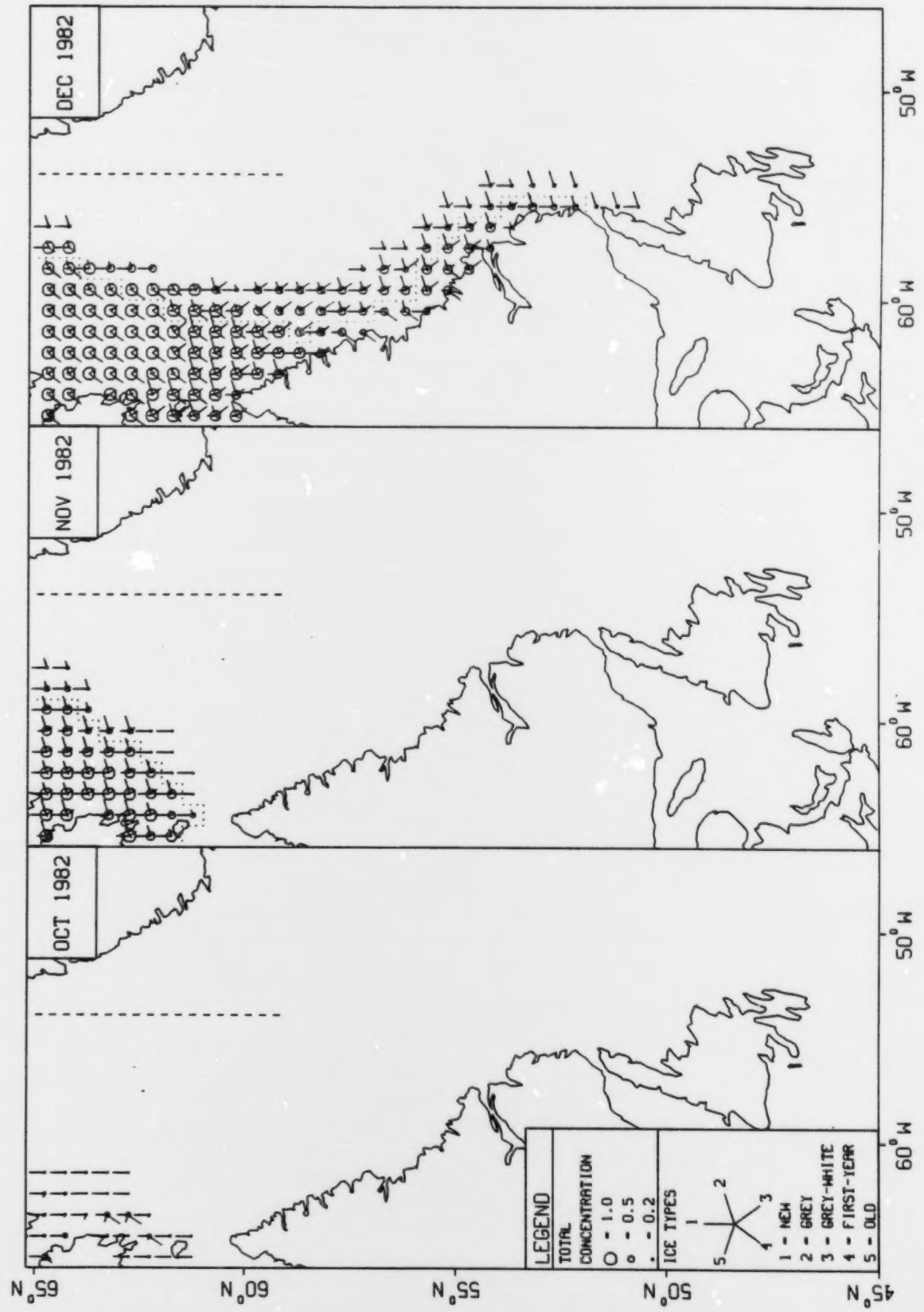
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ICE TYPES
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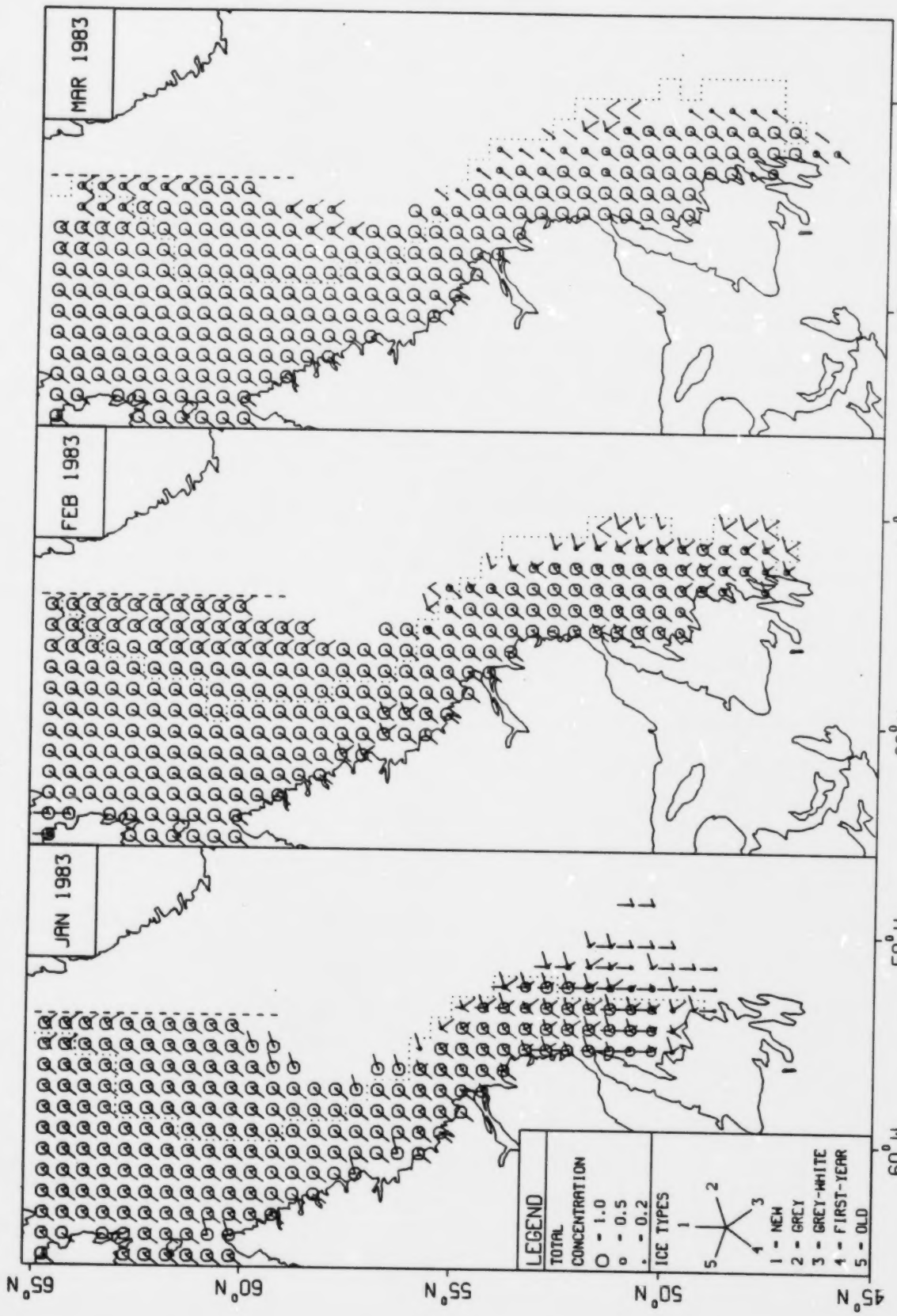
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ICE TYPES
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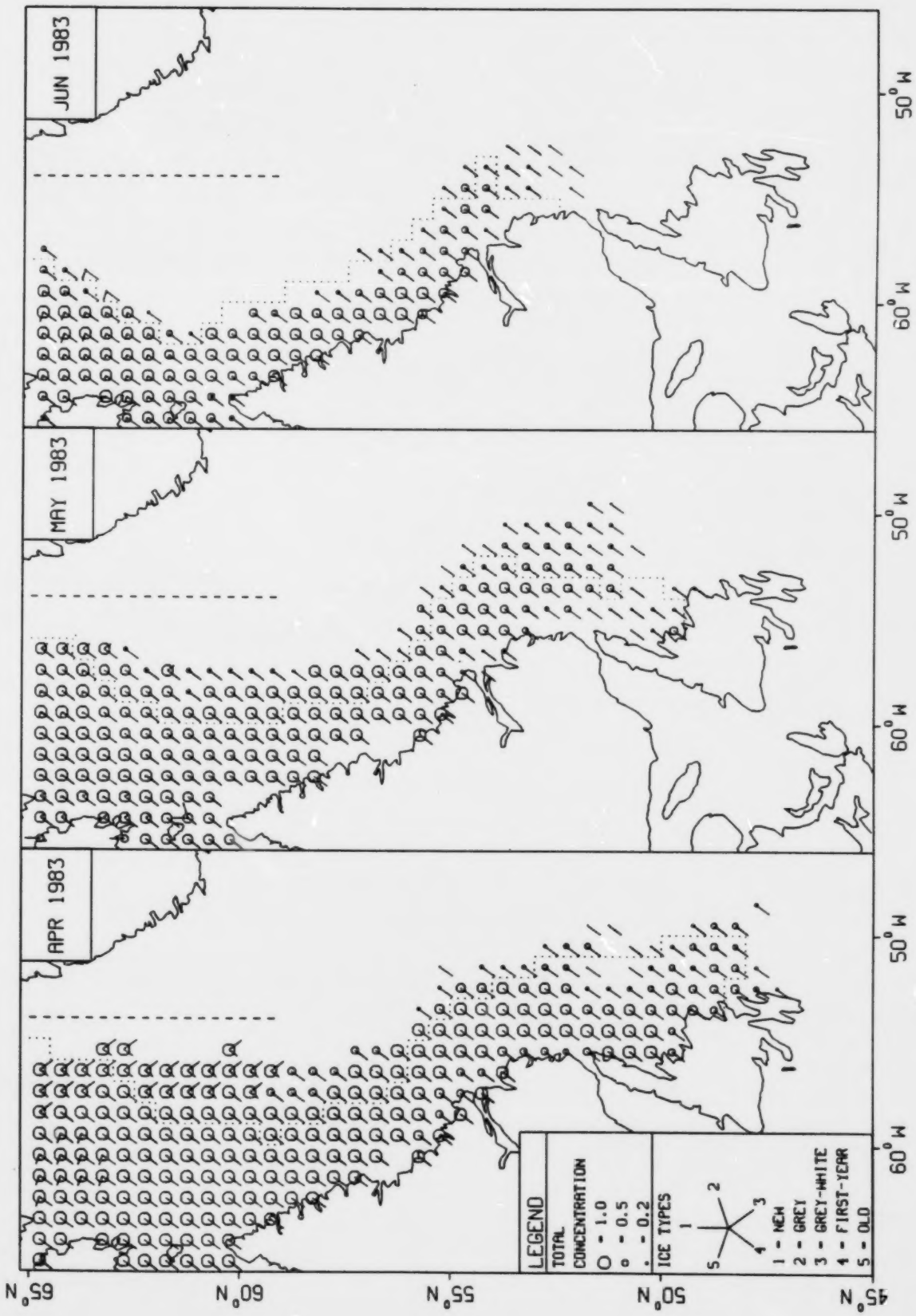
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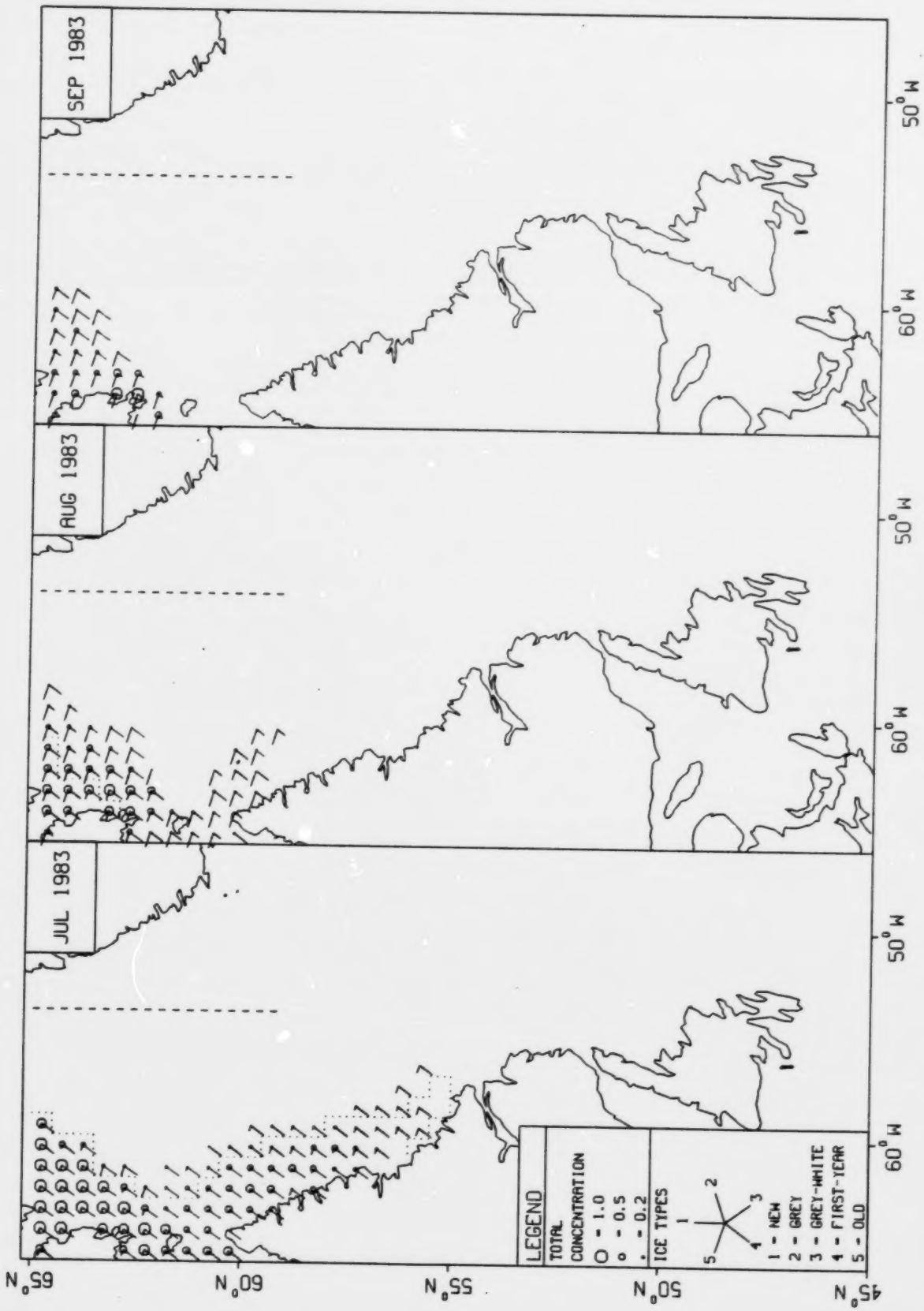
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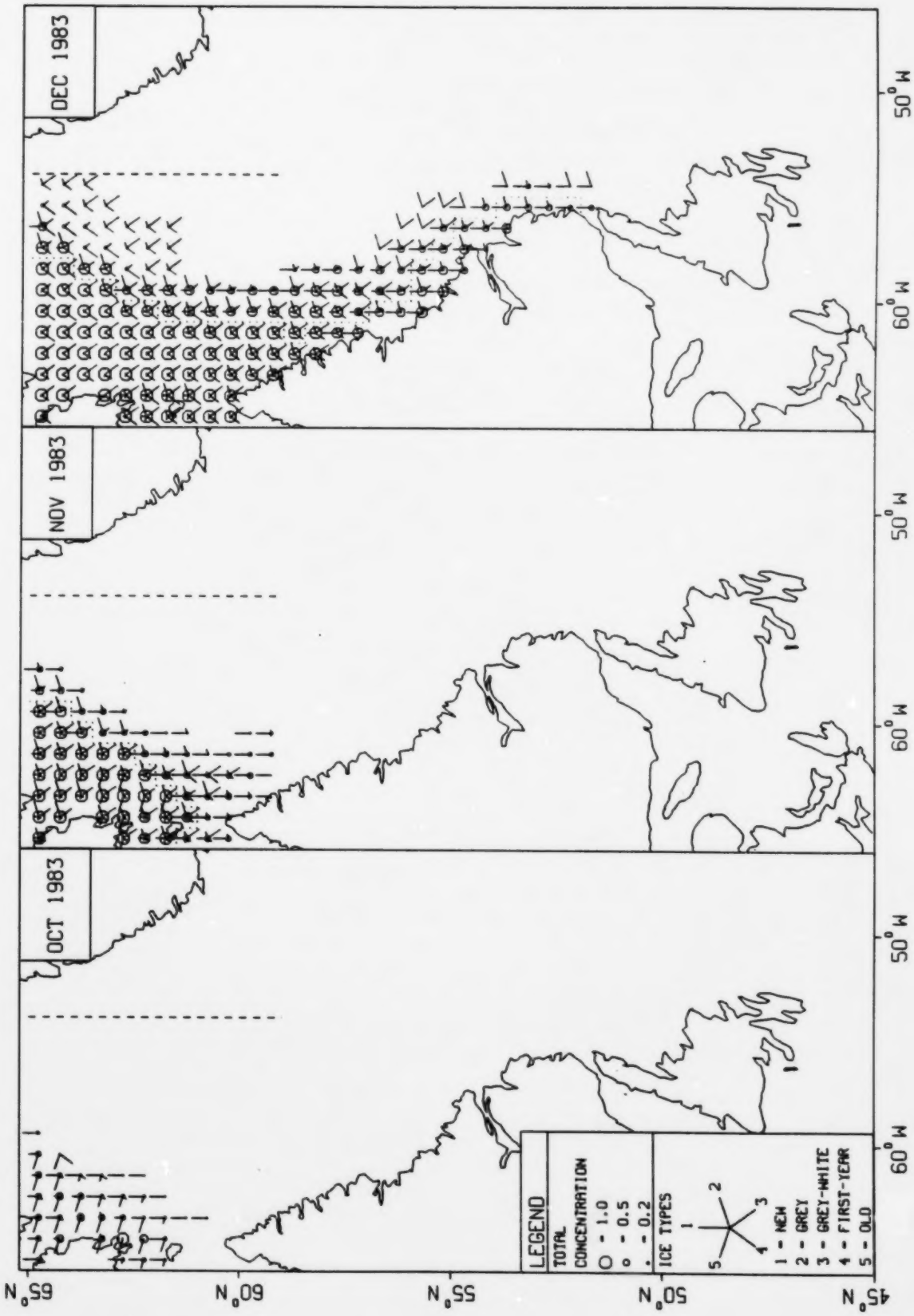
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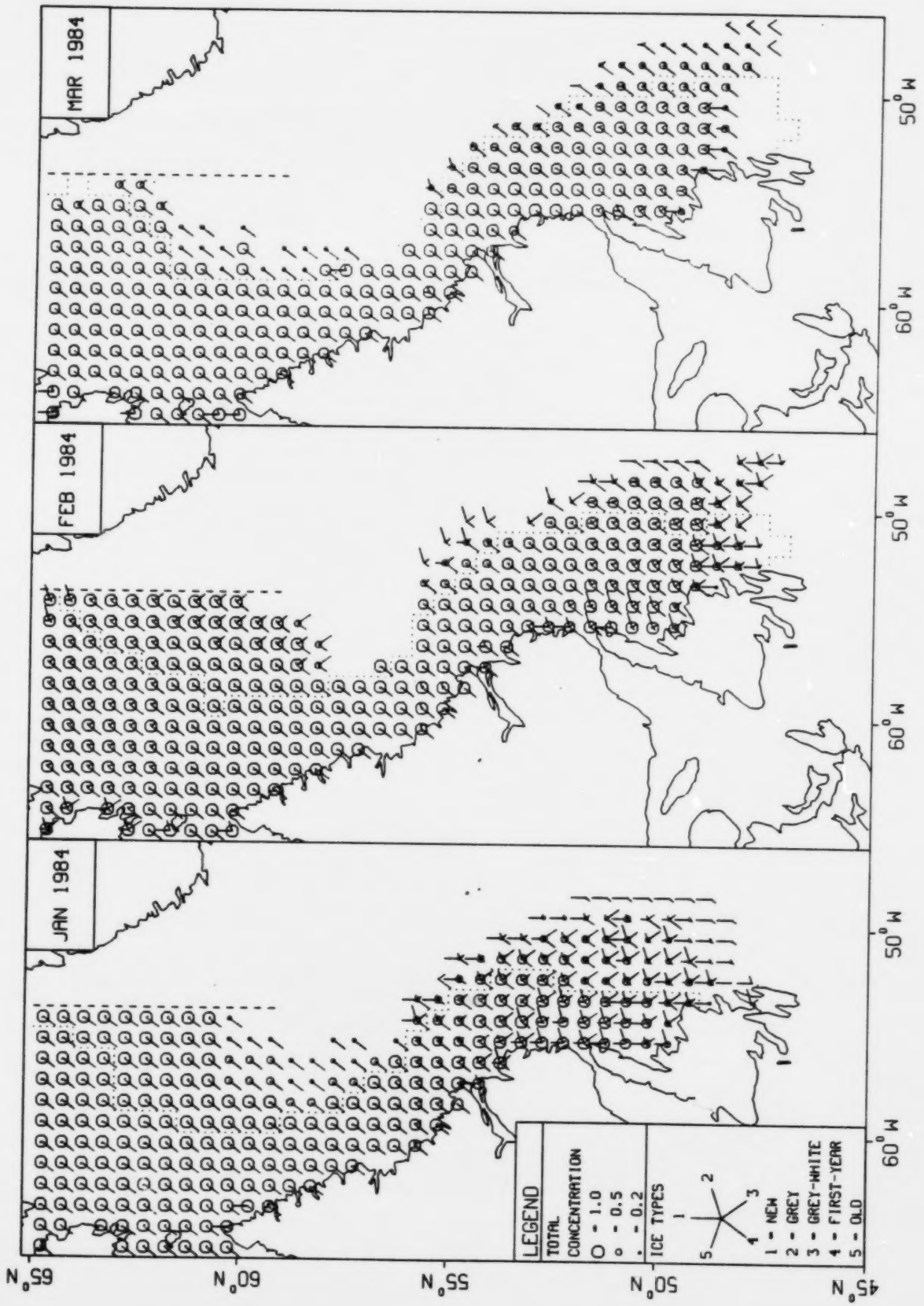
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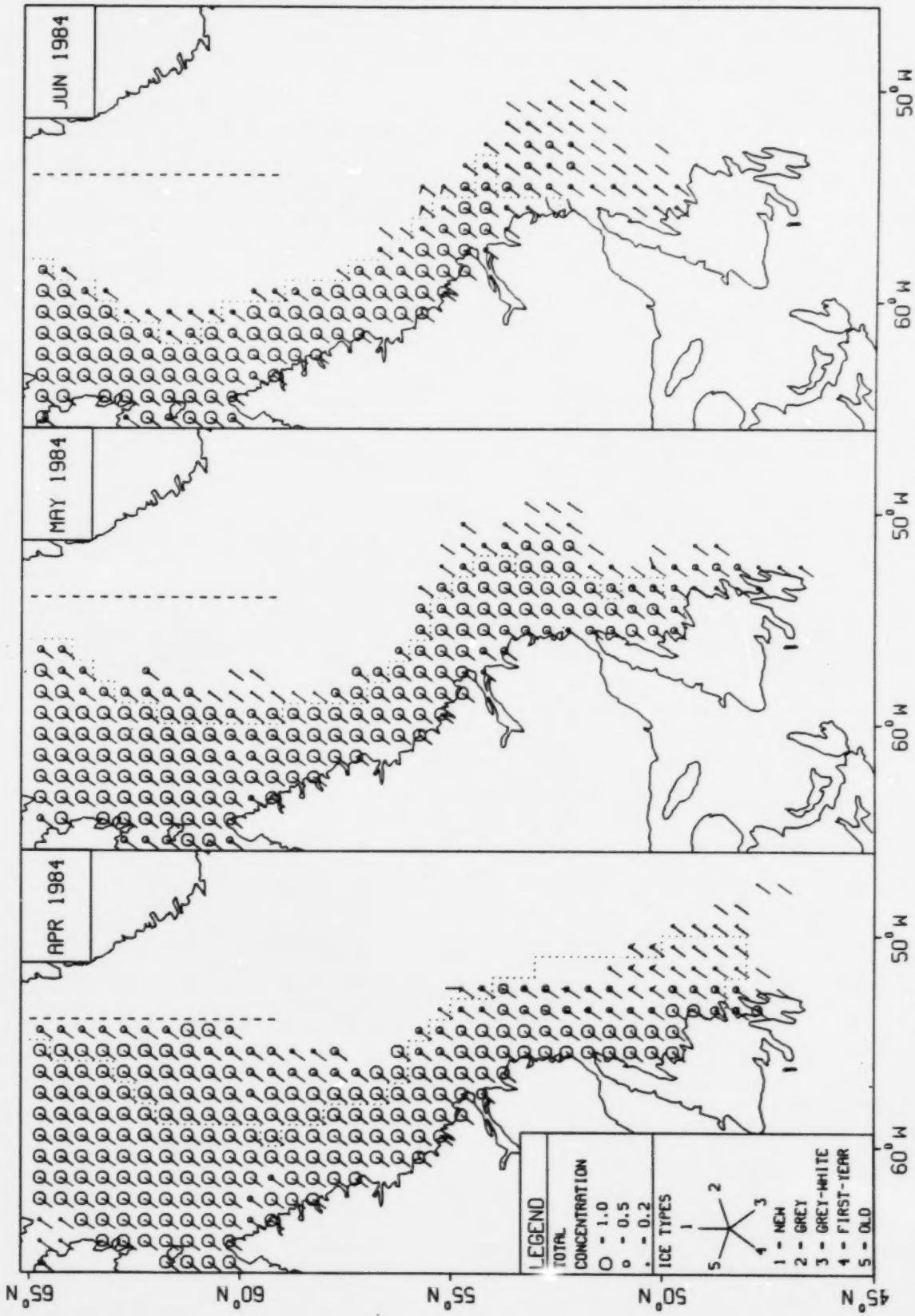
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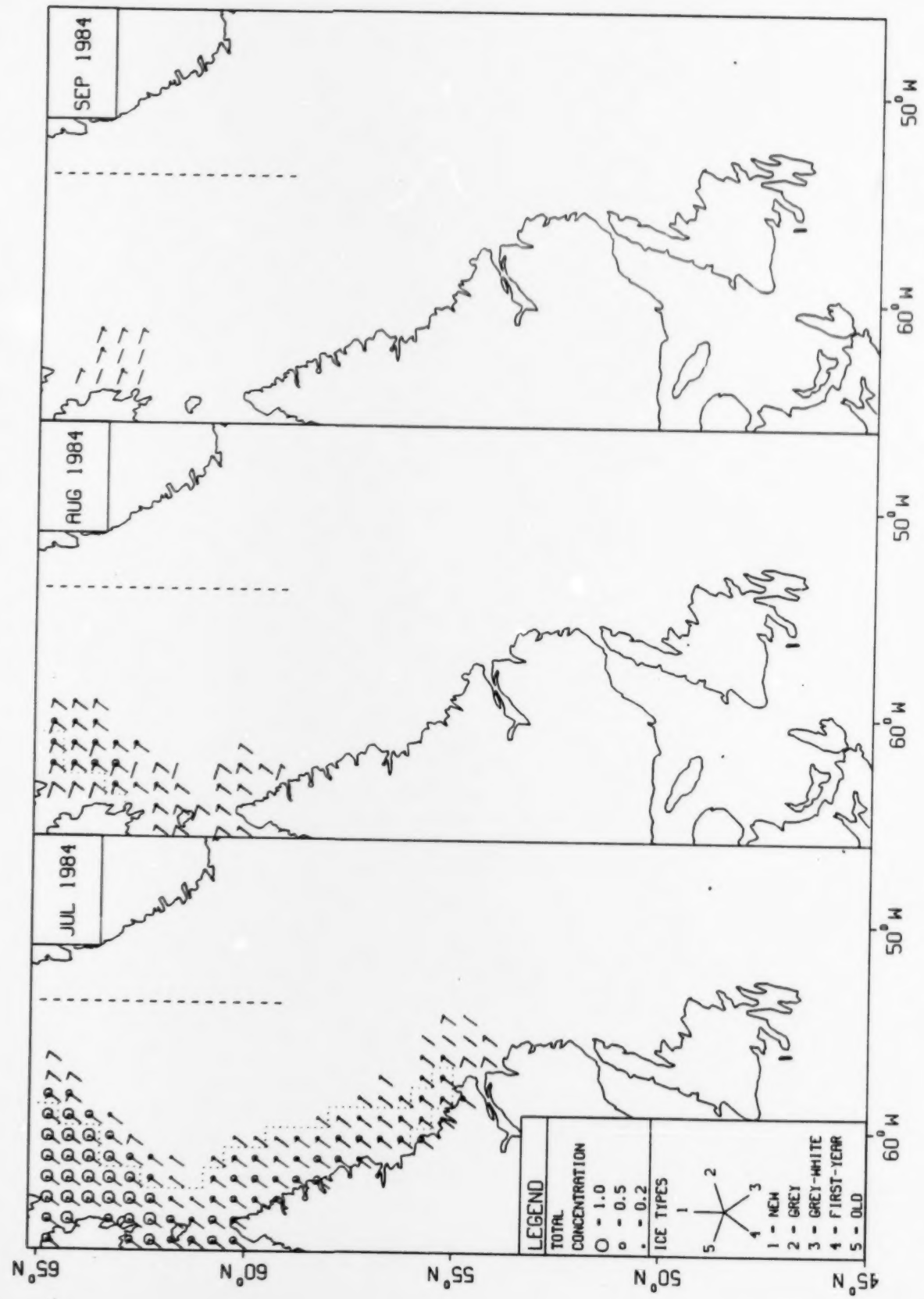
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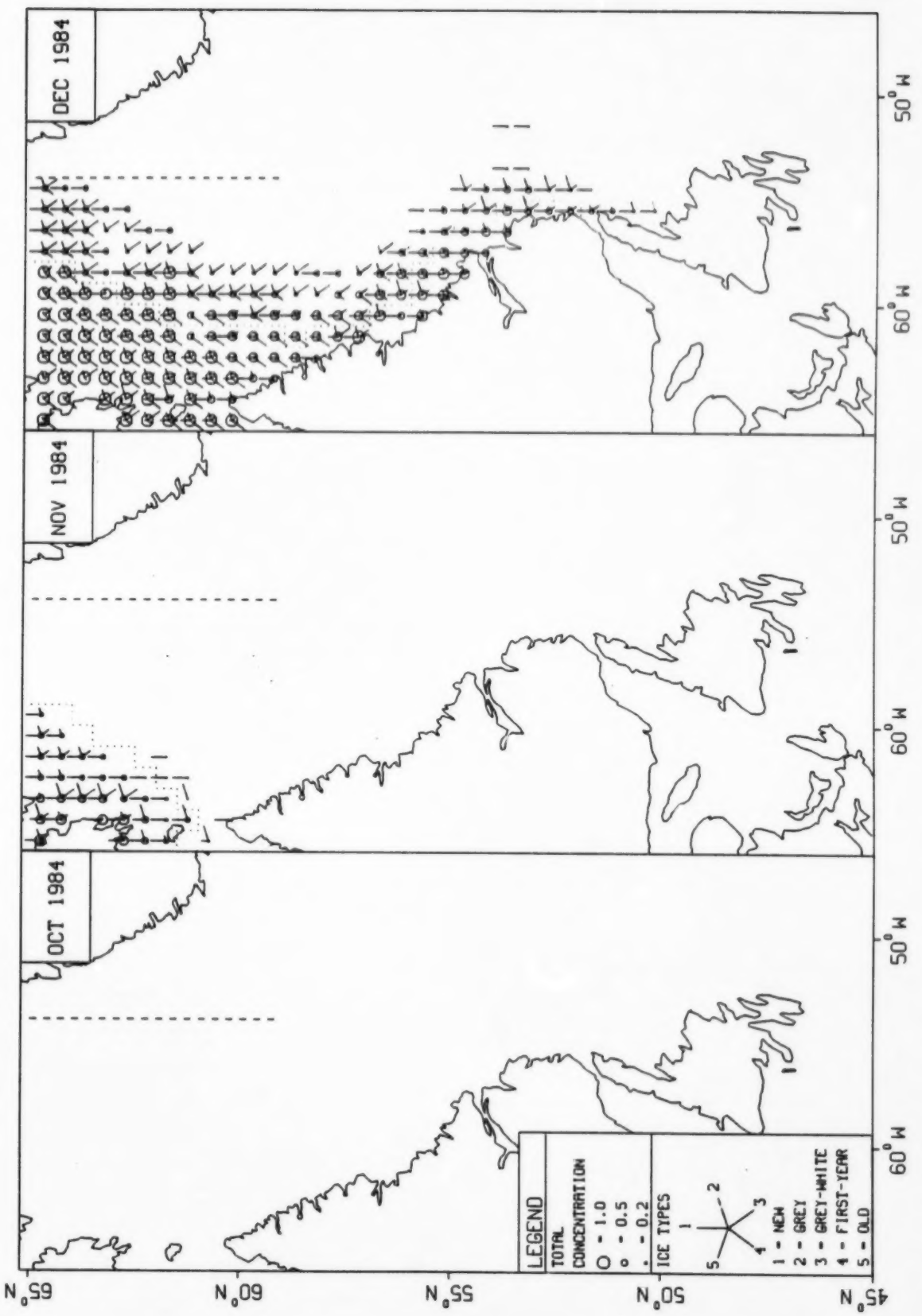
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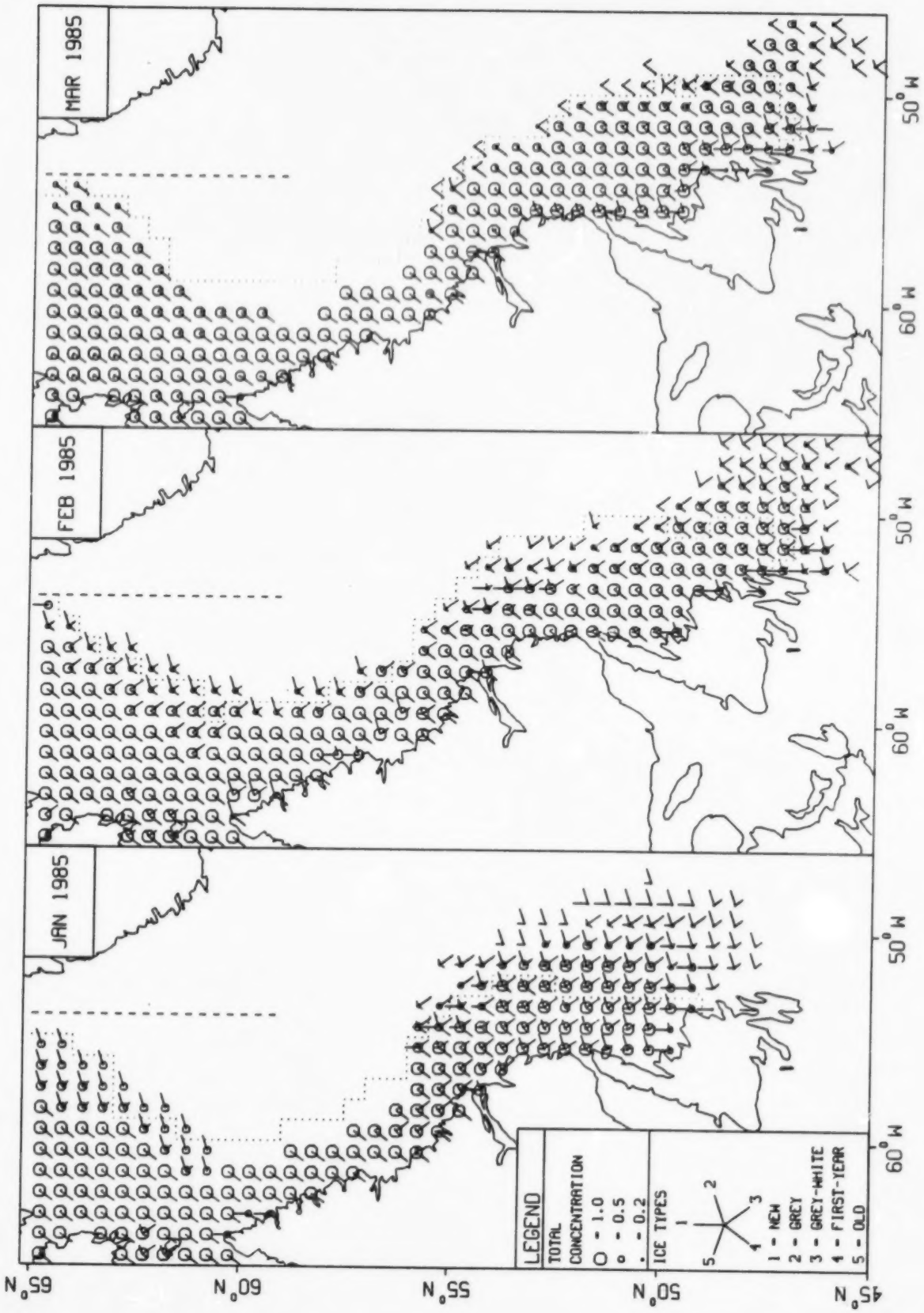
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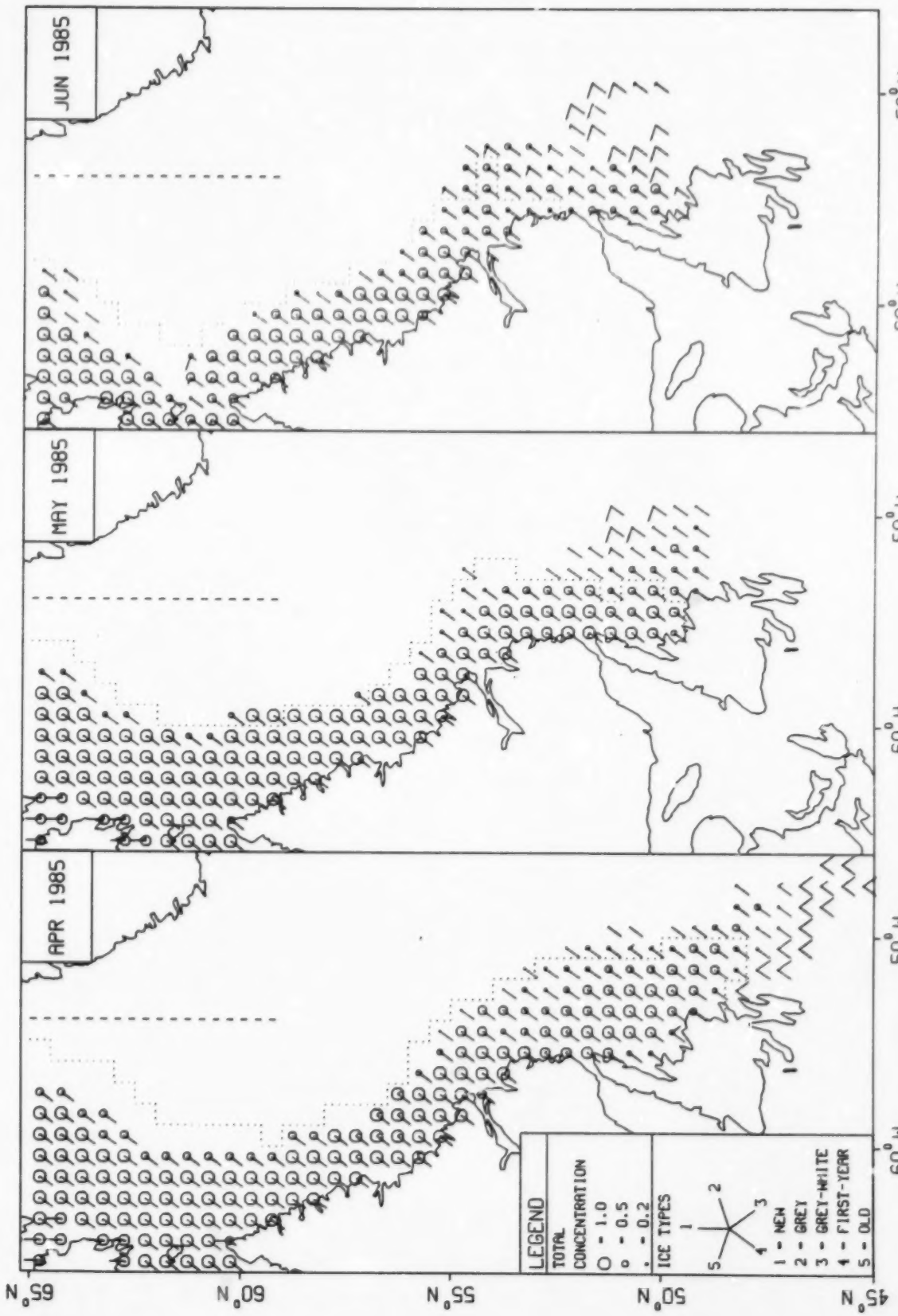
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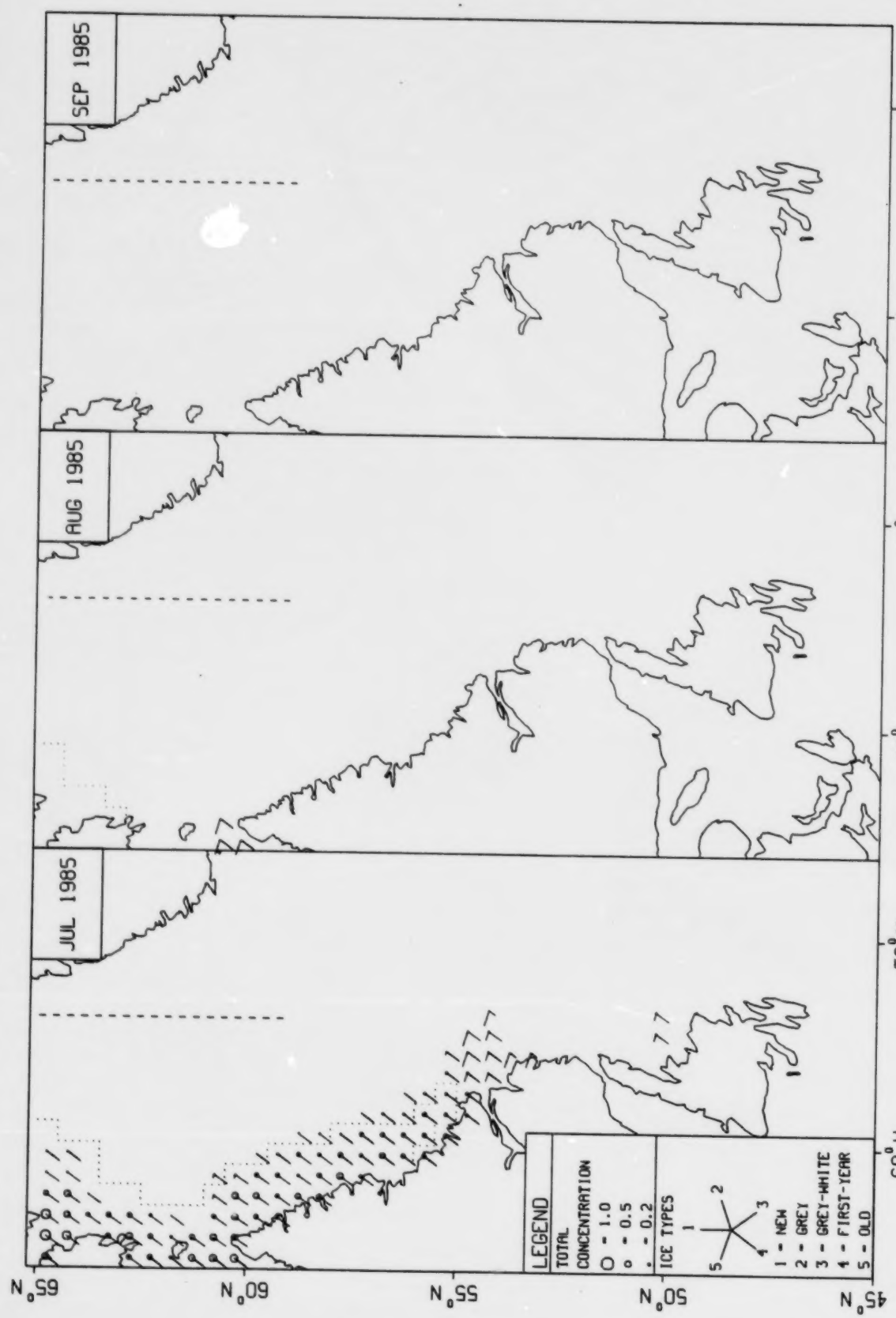
JUL 1985
AUG 1985
SEP 1985
LEGEND
TOTAL CONCENTRATION
O - 1.0
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. - 0.2
ICE TYPES
1 - NEW
2 - GREY
3 - GREY-WHITE
4 - FIRST-YEAR
5 - OLD
65°N
60°N
55°N
50°N
45°N
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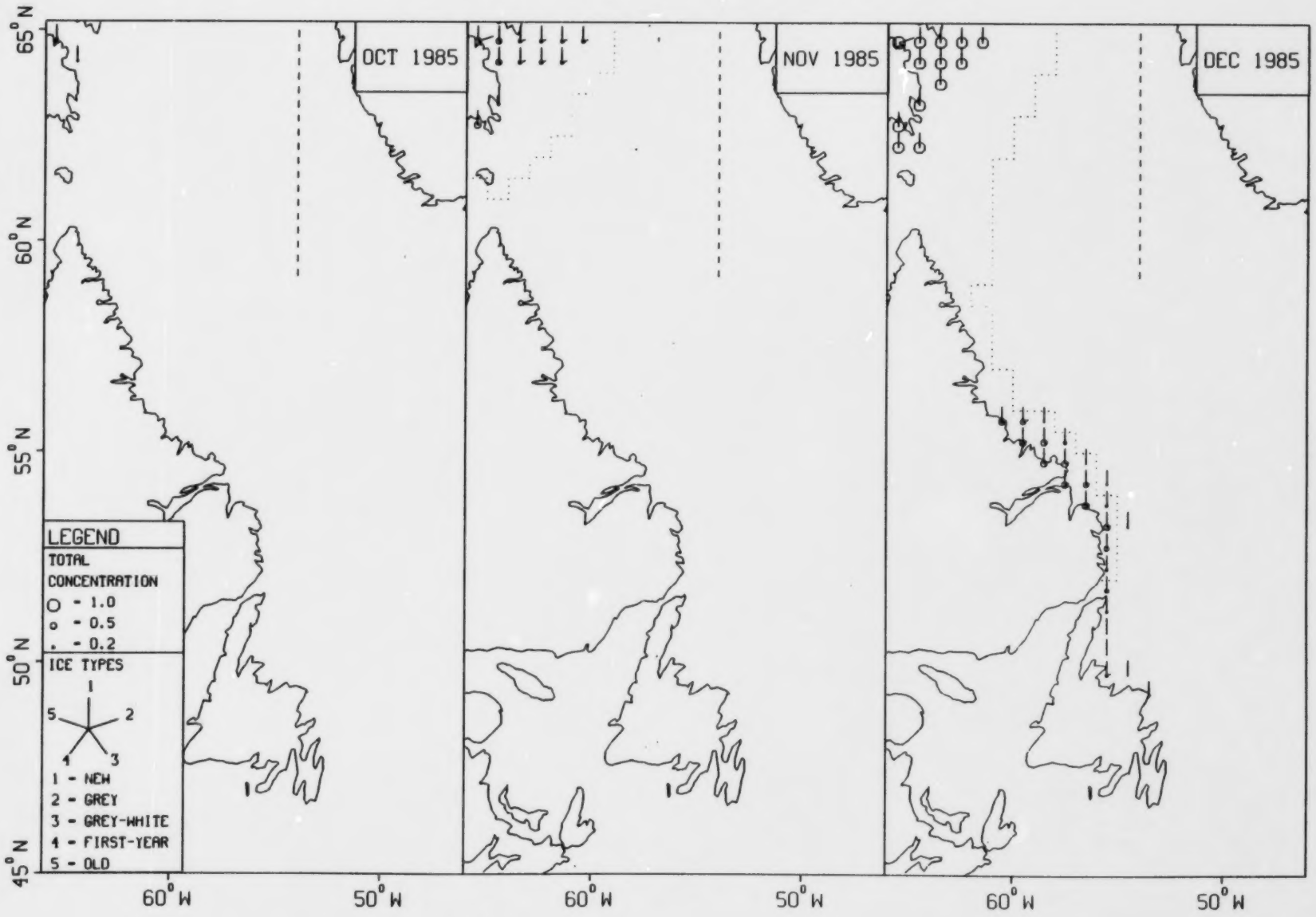
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DEC 1985
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LEGEND
TOTAL CONCENTRATION
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ICE TYPES
1 - NEW
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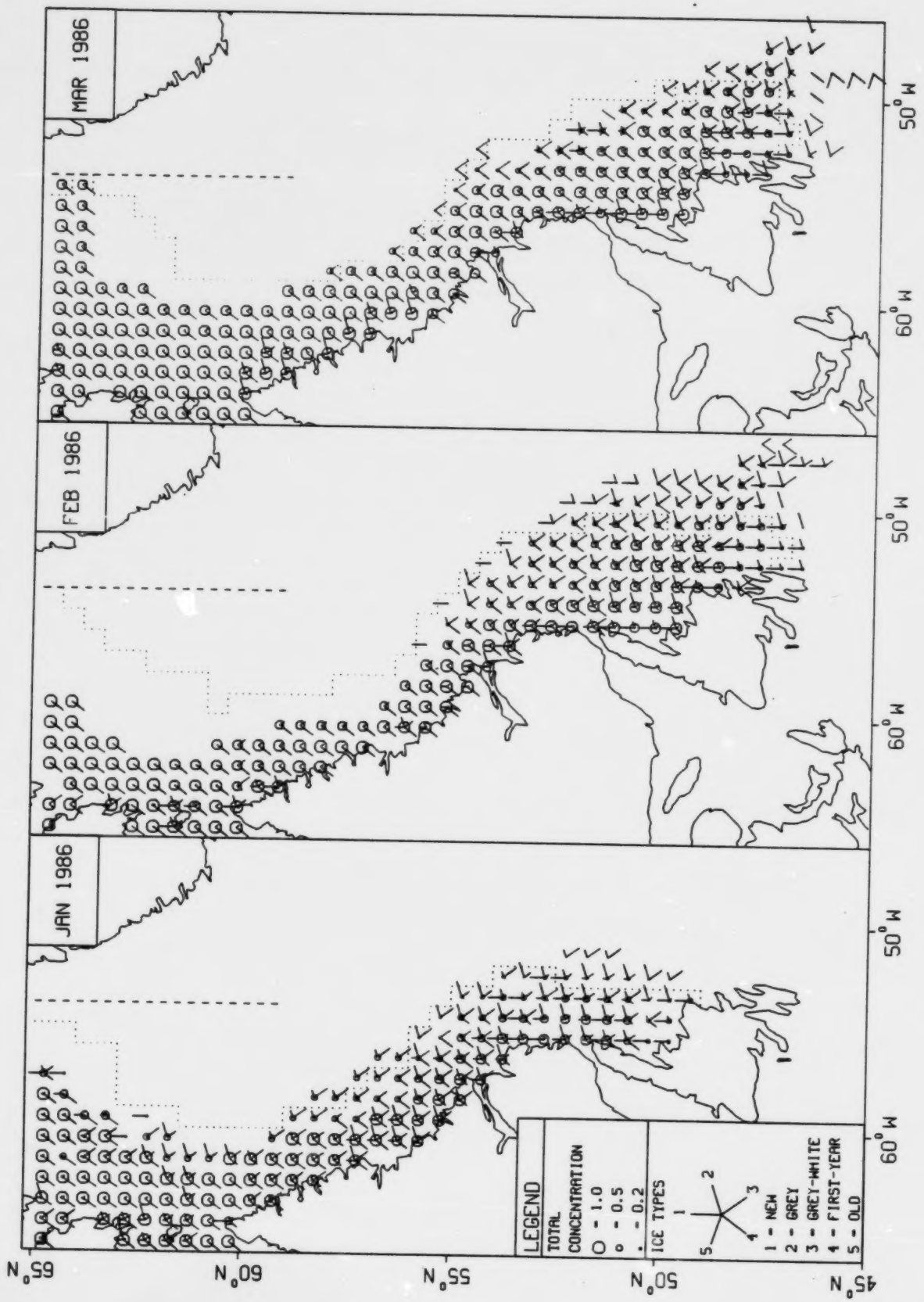
3 - GREY-WHITE
4 - FIRST-YEAR
5 - OLD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ICE TYPES
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2 - GREY
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5 - OLD
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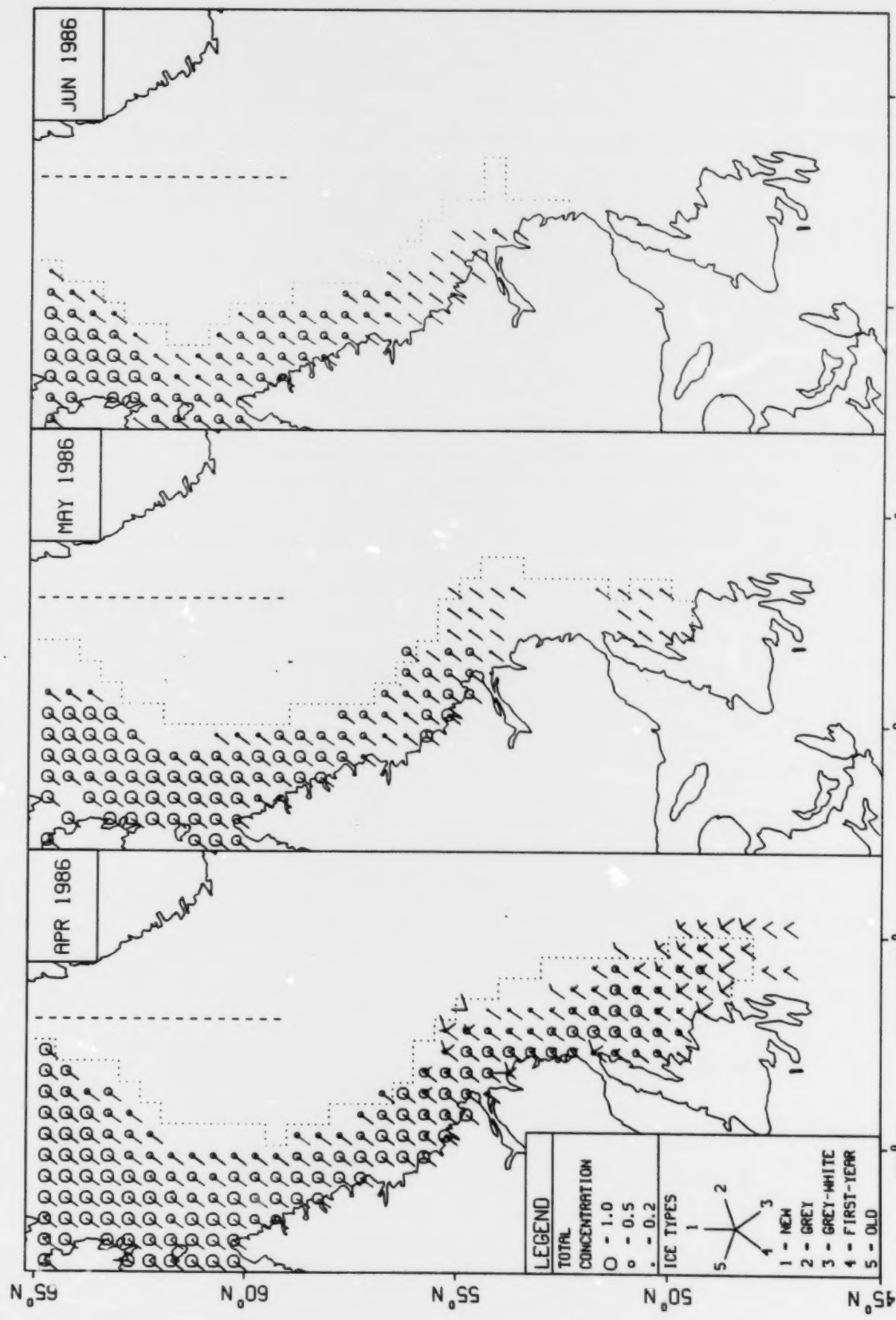
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ICE TYPES
1 - NEW
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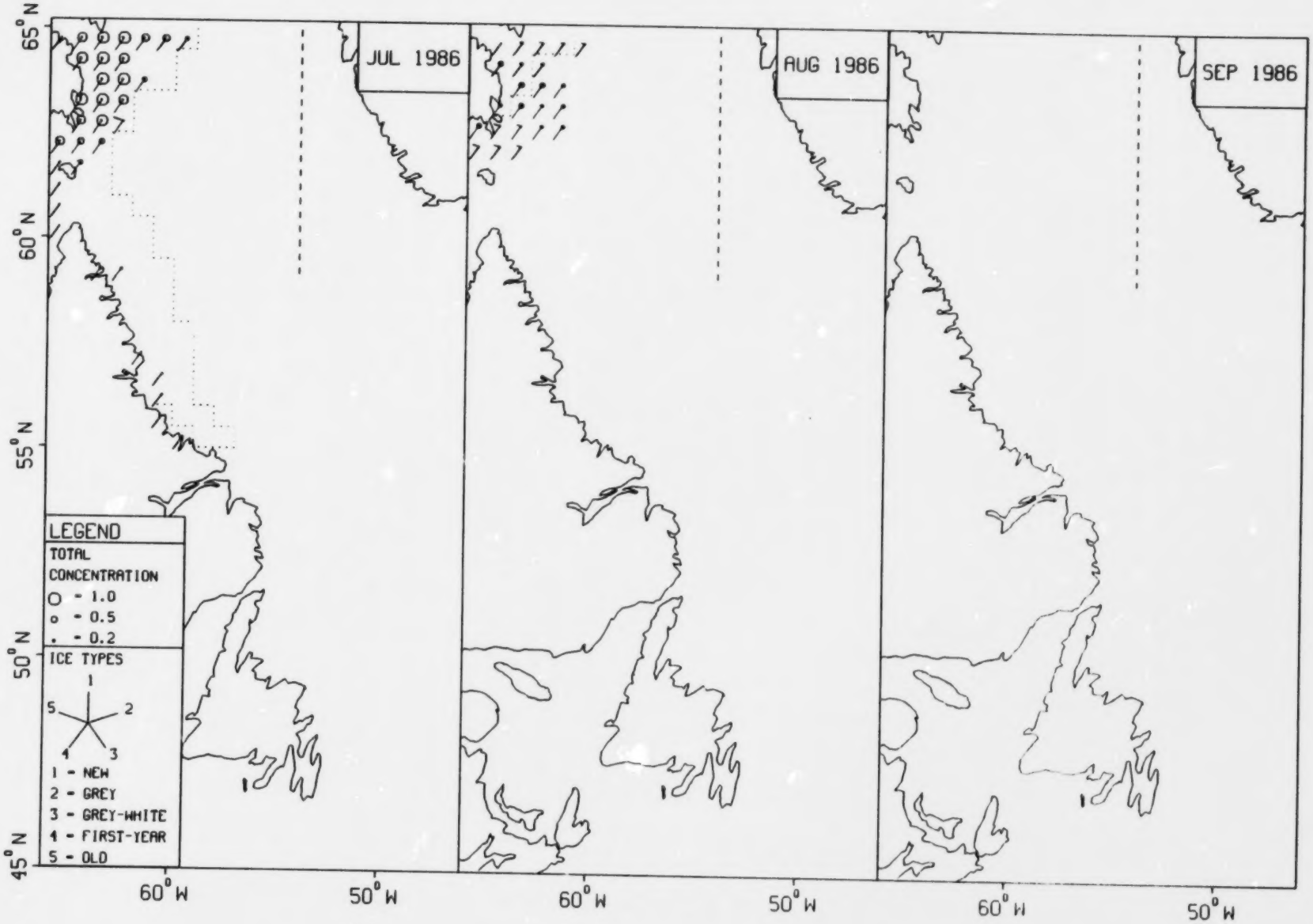
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LEGEND
TOTAL
CONCENTRATION
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. - 0.2
ICE TYPES
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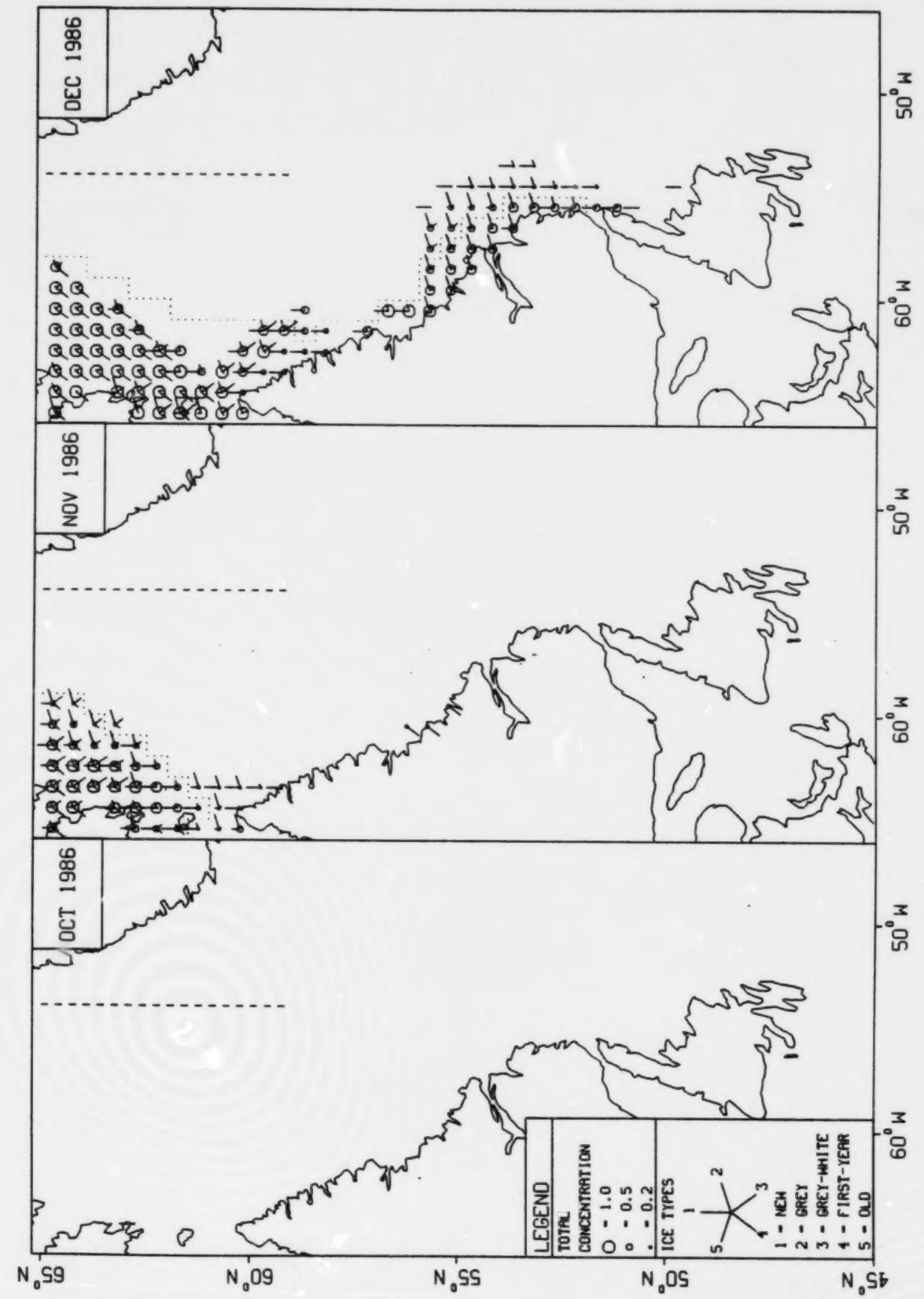
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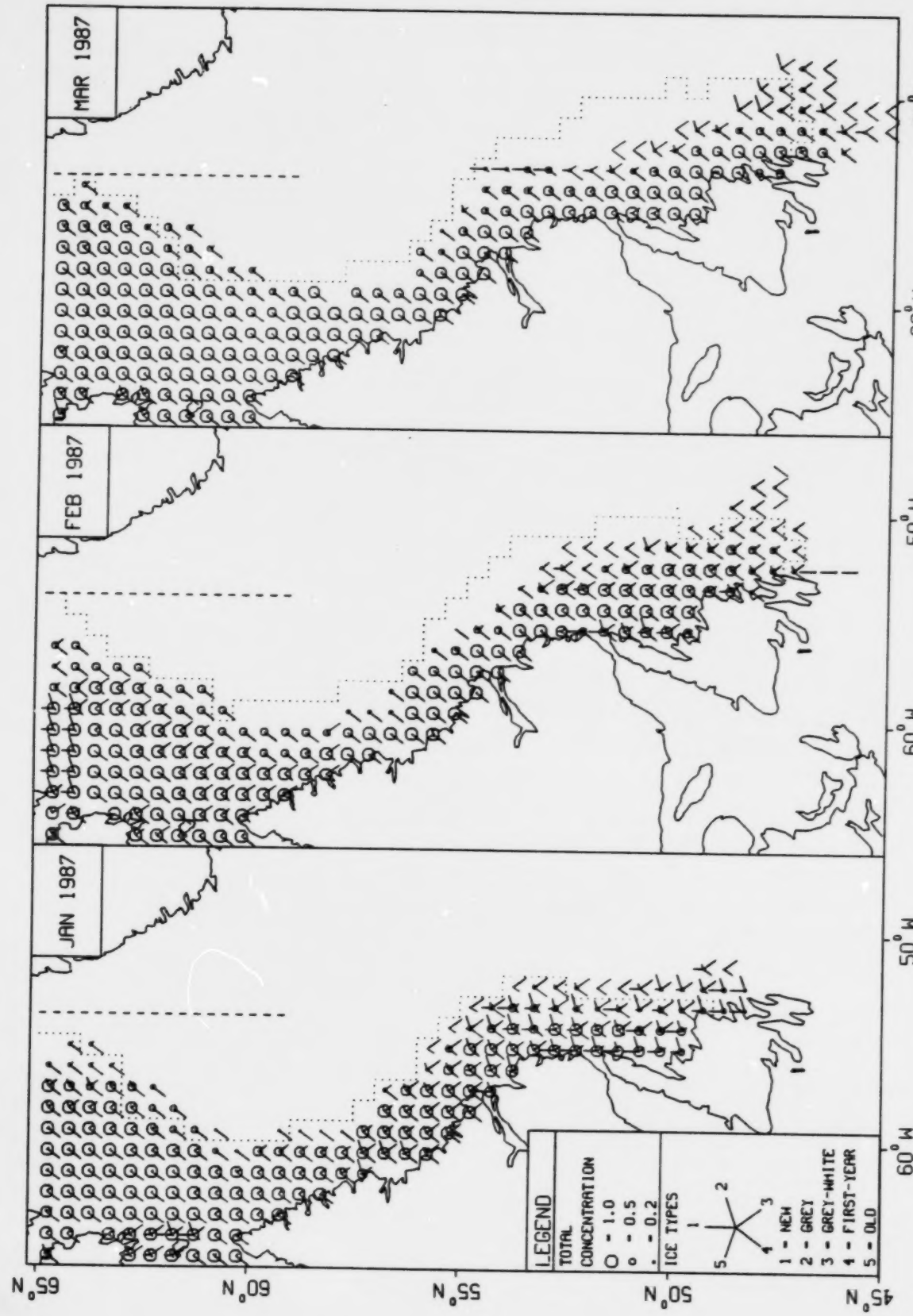
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CONCENTRATION
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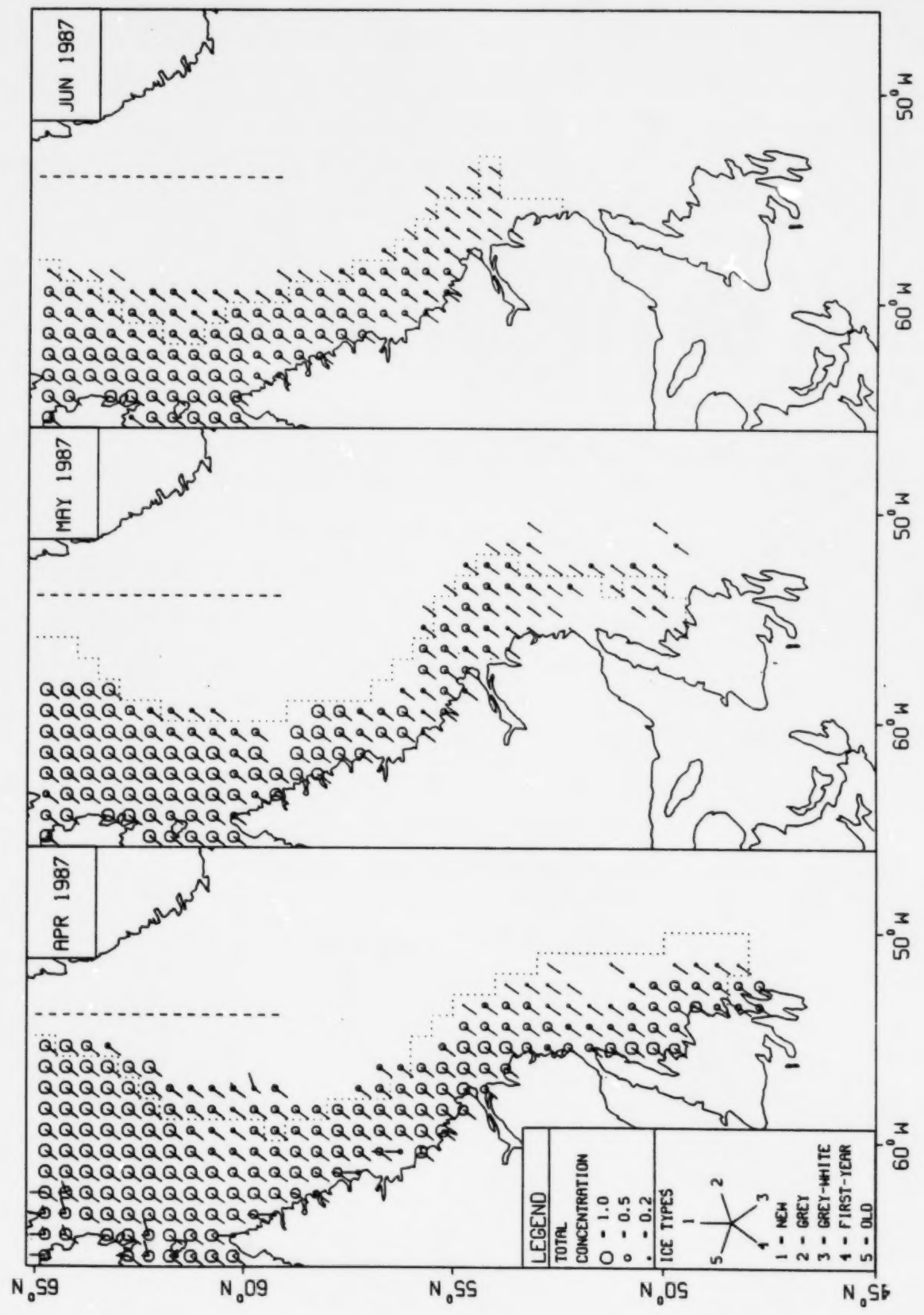
APR 1987
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CONCENTRATION
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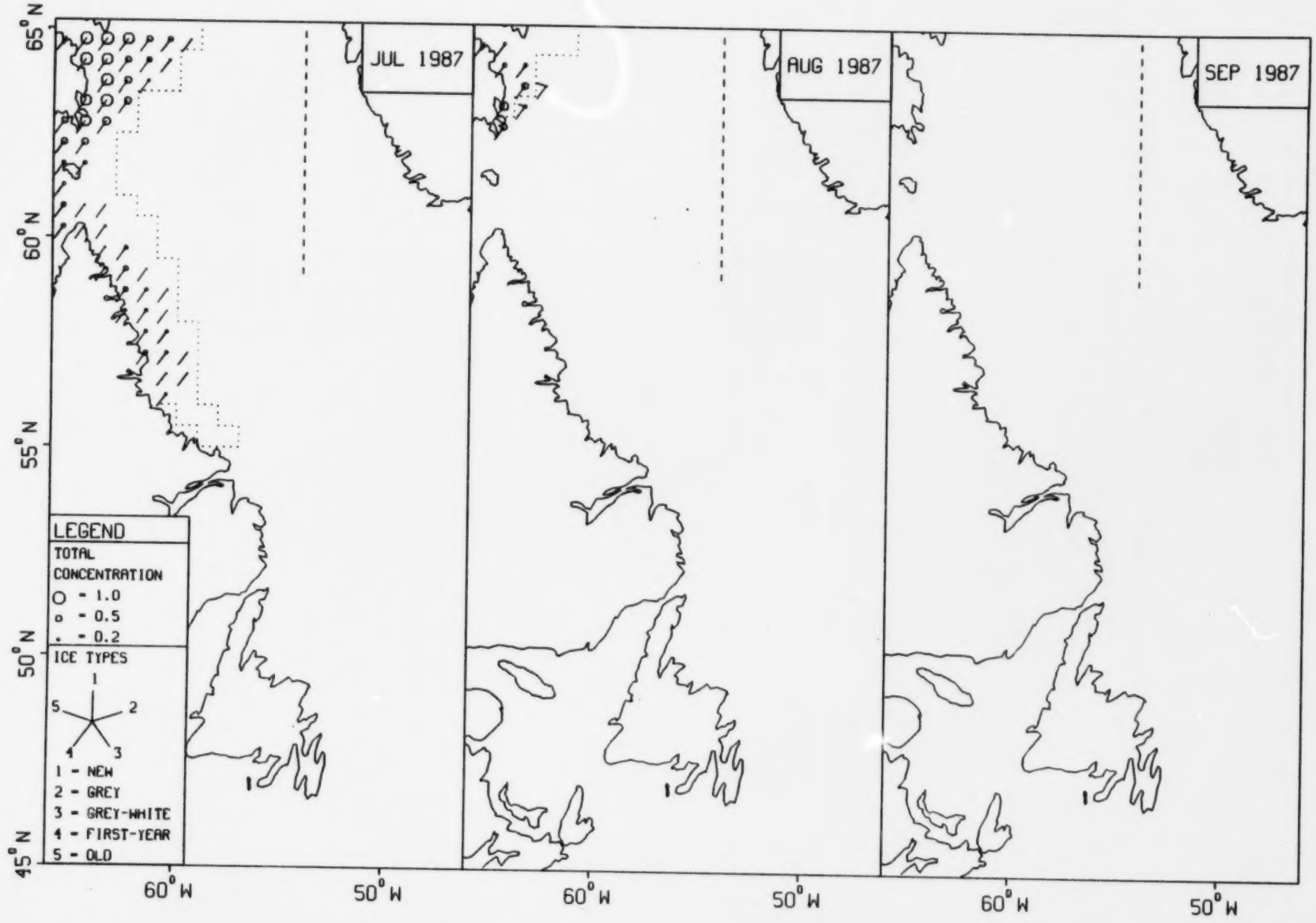
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LEGEND
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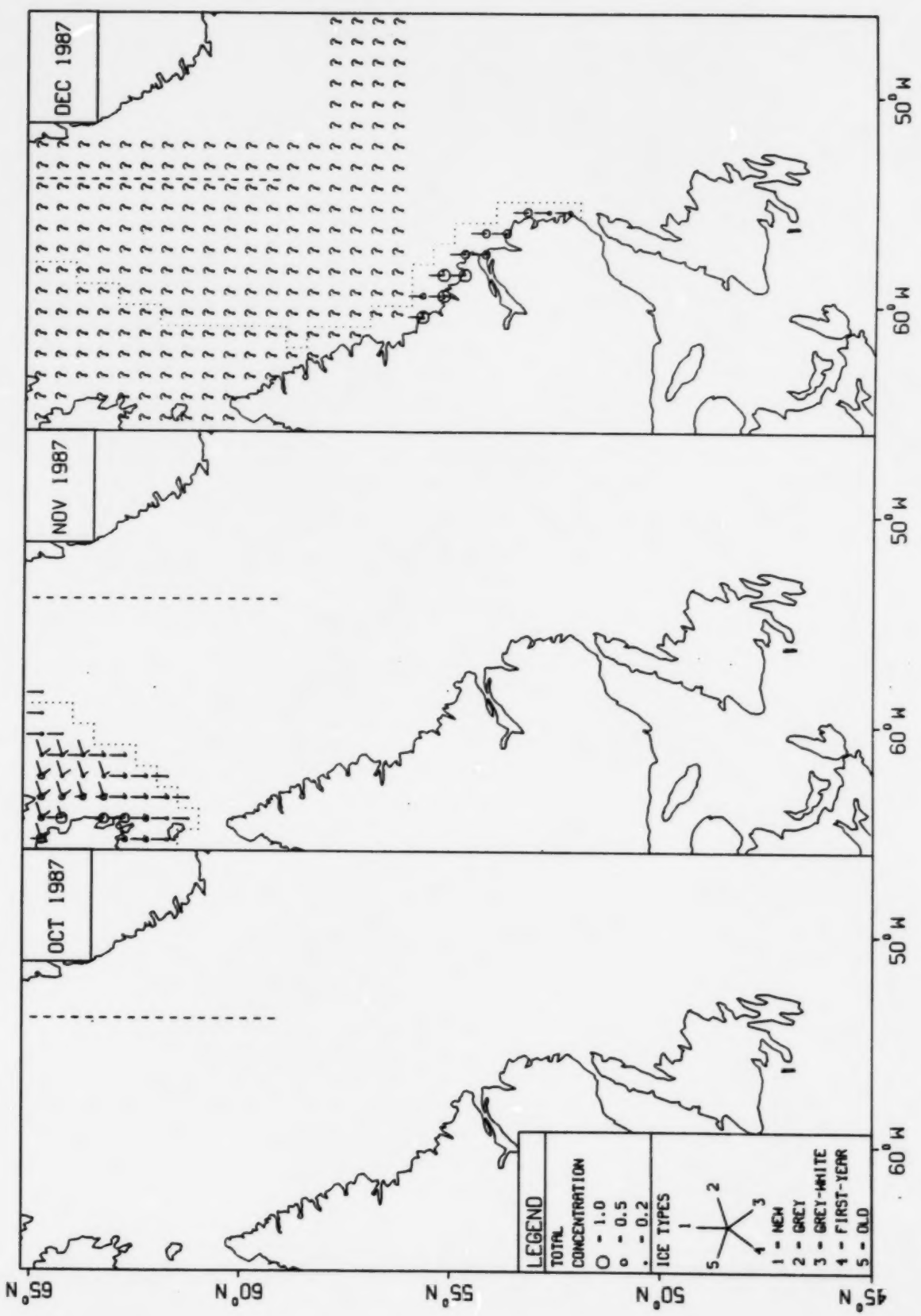
OCT 1987
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LEGEND
TOTAL CONCENTRATION
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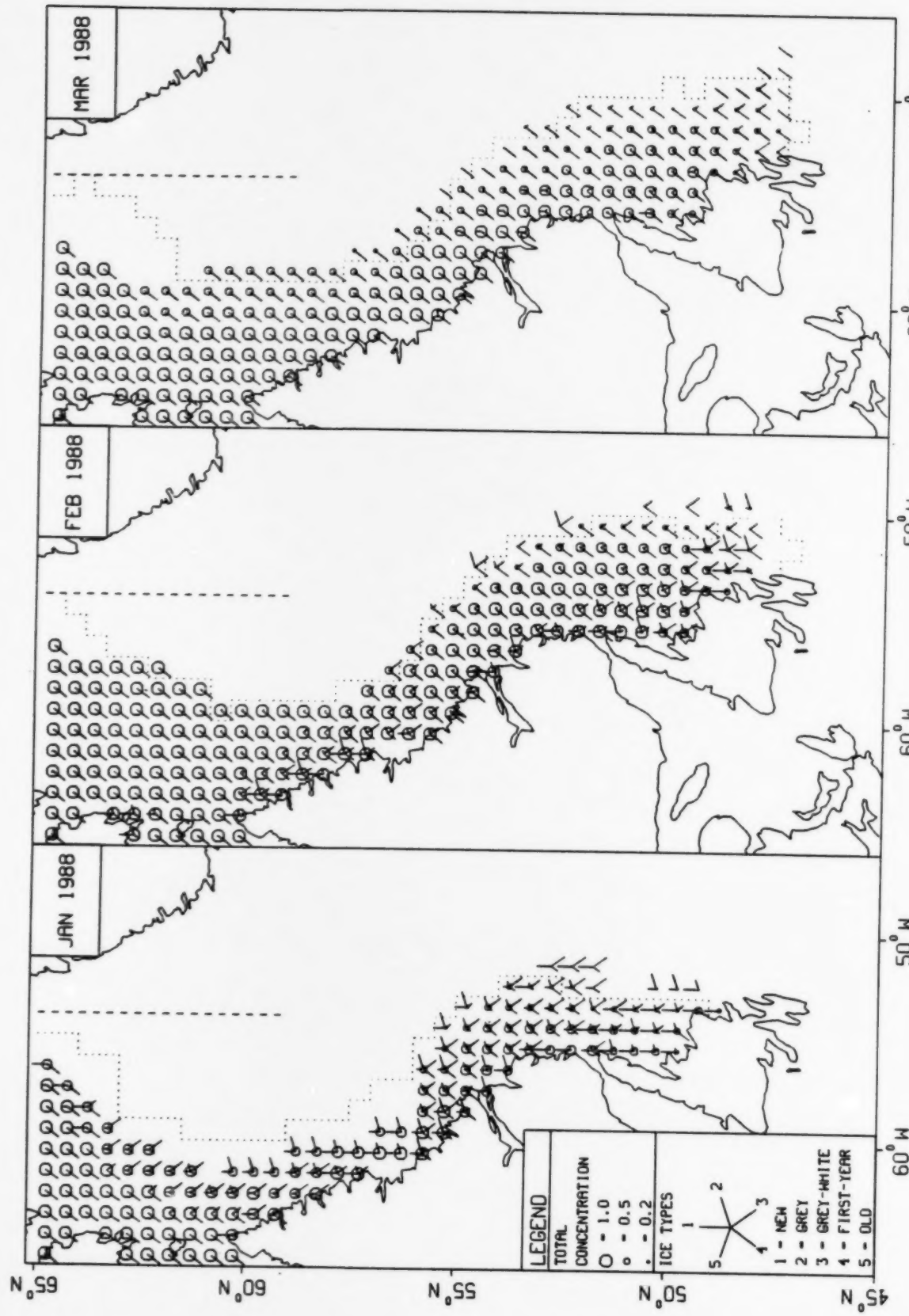
MAR 1988
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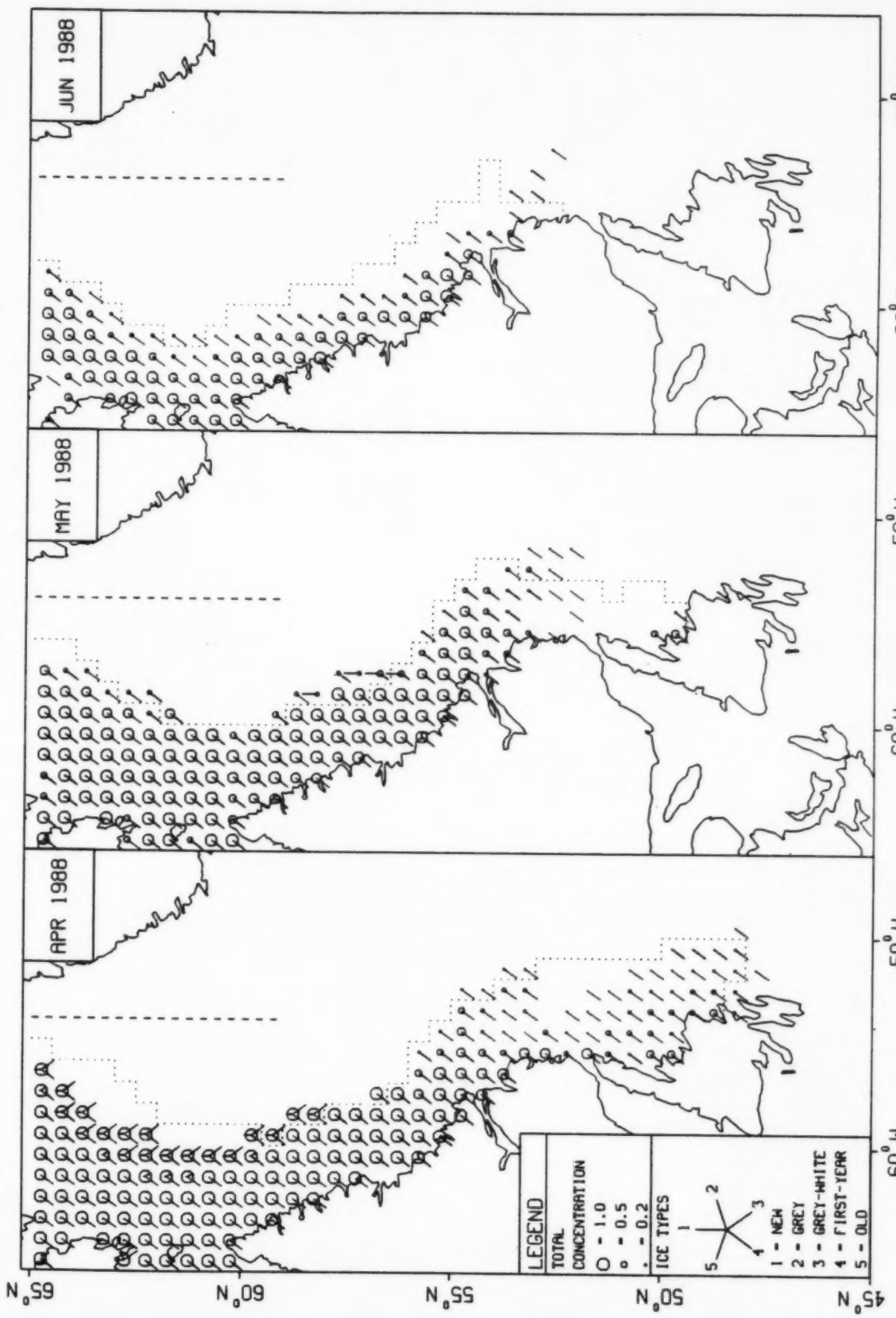
APR 1988
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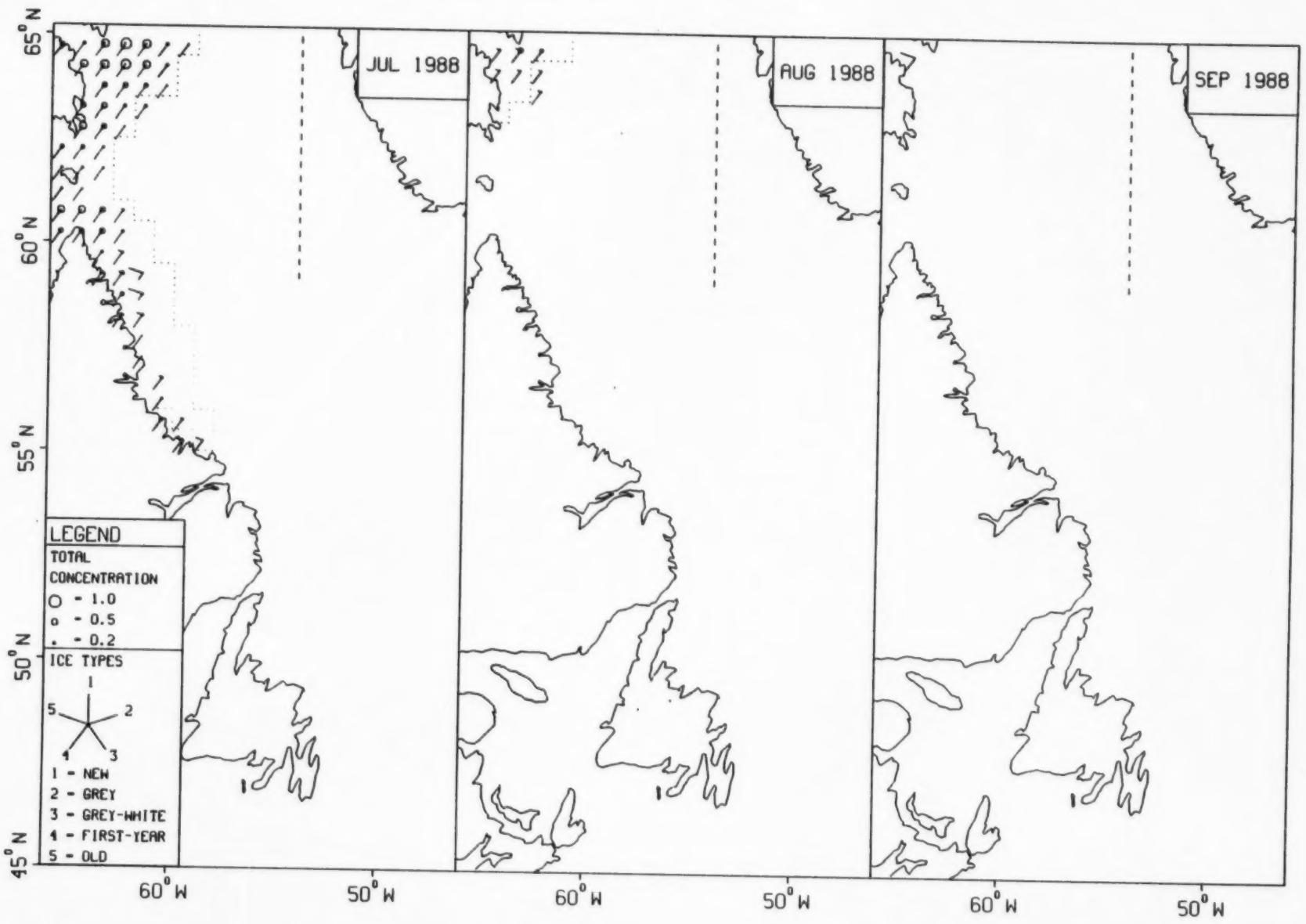
JUL 1988
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